PROCEEDINGS

OF THE

ASSOCIATION OF MUNICIPAL AND SANITARY ENGINEERS AND SURVEYORS.

VOLUME VI.—1879-80.

EDITED BY

LEWIS ANGELL?

GRAHAM SMITH,

ASSOC. M.I.C.E.,

PAST PRESIDENT OF THE LIVERPOOL ENGINEERING SOCIETY

(*Secretary of the Association*).

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Northampton	J. H. Pidcock.
North Bierley	J. Cook.
Oldbury	J. Devis.
Oswestry	E. B. Smith.
Over Darwen	W. Stubbs.
Oxford	W. H. White.
Plymouth	H. Alty.
"	R. Hodge.
Pontefract	W. Scriven.
Prescot	W. Goldsworth.
Prestwich	S. C. Trapp.
Reading	A. W. Parry.
Redditch	T. W. Baylis.
Reigate	J. H. C. B. Hornibrook.
Rhyl	Robt. Hughes.
Rochdale	T. Hewson.
Rochester	W. Banks.
Rotherham	G. Jennings.
Ryde	F. Newman.
Sale	A. G. McBeath.
Scarborough	J. Petch.
Selby, Yorkshire	J. Holmes.
Sheerness	H. S. Pollard.
Sheffield	R. Davidson.
"	P. B. Coghlan.
Shildon and East Thickley ..	J. Craggs.
Shrewsbury	J. G. Butler.
Skelton	John Downie.
Solihull, Warwickshire	A. T. Davis.
Southampton	J. Lemon.
Southport	W. Crabtree.
South Shields	M. Hall.
South Stockton	S. E. Thorrold.
Stalybridge	Amos Lee.
Stapleton	J. P. Curtis.
Stockton-on-Tees	J. Hall.
Stoke-on-Trent	C. Lynam.
Stratford-on-Avon	T. T. Allen.
Stretford	H. Royle.
Stroud	J. P. Lofthouse.

St. George, Gloucestershire ..	W. Dawson.
St. Helens, Lancashire	J. Hart.
St. Thomas, near Exeter	S. Churchward.
Swansea	C. Cousins.
Swindon, Wilts	T. V. H. Davison.
Swinton, near Rotherham	J. C. Haller.
Taunton	J. H. Smith.
Teddington	T. Goodchild.
Tewkesbury, Gloucestershire ..	W. H. Gray.
Tipton, Staffordshire	W. M. Jepson.
Tiverton, Devon	Wm. Rowe.
Tonbridge	W. Noot.
Torquay	J. Little.
Town Malling	F. J. C. May.
Toxteth Park, Liverpool	J. A. Hall.
Tranmere	W. A. Richardson.
Tunstall	A. R. Wood.
Twickenham	H. M. Ramsay.
Tynemouth	J. P. Spencer.
Ventnor	R. S. Scott.
"	J. G. Livesay.
Wakefield	T. V. Edwards.
"	J. Pagan.
Wallasey	J. T. Lea.
Walsall	W. J. Boys.
Walthamstow	G. B. Jerram.
Wanstead	J. T. Bressey.
Warminster	T. Cruse.
Warrington	T. Longdin.
Warwick	T. Broughton.
Waterloo, Liverpool	R. Thompson.
Watford	C. C. Lovejoy.
Wednesbury	J. W. Fereday.
Wellingborough	E. Sharman.
West Bromwich, Staffordshire ..	J. T. Eayrs.
West Derby, Liverpool	E. H. Allies.
West Ham, London	L. Angell.
Weymouth and Melcombe Regis ..	W. B. Morgan.
Whitworth	Thos. Holt.
Willenhall	B. Baker.
Willesden	O. C. Robson.
Willington Quay, Northumberland	P. W. Thomson.
Withington	J. Swarbrick.
Wolverhampton	G. E. Thoms.
Worksop	J. Allsopp.
Wrexham	J. W. M. Smith.

RULES OF THE ASSOCIATION.

I.—That the Society be named the "Association of Municipal and Sanitary Engineers and Surveyors."

II.—That the objects of the Association be—

a. The promotion and interchange among its Members of that species of knowledge and practice which falls within the department of an Engineer or Surveyor engaged in the discharge of the duties imposed by the Public Health, Local Government, and other Sanitary Acts.

b. The promotion of the professional interests of the Members.

c. The general promotion of the objects of Sanitary Science.

III.—That the Association consist of Civil Engineers and Surveyors holding permanent appointments under the various Municipal and Sanitary Authorities within the control of the Local Government Board, and such Honorary Members as shall be elected by the Council. Members who retire from their official position are eligible for re-election by the Council.

IV.—That the Affairs of the Association be governed by a Council, consisting of a President, Three Vice-Presidents, Twelve Members, and an Honorary Secretary, to be elected annually. The Past Presidents and the District Secretaries for the time being shall also be Members of the Council.

V.—That the Council shall nominate one name for President, six for Vice-Presidents, one for Secretary, and twenty-two Ordinary Members from whom to elect the Council. Such Nominations shall be printed and sent to each Member of the Association not less than thirty days previous to the Annual Meeting. Every Member shall be entitled to vote for or erase any of such Nominations, or substitute other names, subject in all cases to the limits of Rule IV., and return the same within seven days of the date of issue, and the Members who shall obtain a majority of votes shall respectively be duly elected President, Vice-Presidents, Members of Council, and Honorary Secretary for the ensuing year.

VI.—That the Association be formed into District Committees which shall include the whole of the Members. Such Committees shall meet from time to time, in convenient centres, for the discussion of matters of local and general interest connected with the Association. Each District Committee shall appoint a Local Secretary, who will keep records of local proceedings, and communicate with the Council. No District Committee or Local Secretary shall be entitled either to represent or act on behalf of the Association.

VII.—That a General Meeting and Conference of the Association shall be held annually in such towns, in rotation, as may afford convenient centres for assembling the Members.

VIII.—That an entrance-fee of One Guinea, and a subscription of One Guinea per annum, from Civil Engineers and Surveyors under Rule III., shall constitute Membership of the Association.

ASSOCIATION OF MUNICIPAL AND SANITARY ENGINEERS AND SURVEYORS.

SEVENTH ANNUAL MEETING.

Leeds, *May* 27*th*, 28*th*, *and* 29*th*, 1880.

GENERAL BUSINESS.

The Members having assembled in the Grand Jury Room of the Town Hall, Mr. E. Pritchard, President, took the Chair, and the Minutes of the Annual Meeting held in London, July 1879, were read, confirmed, and signed.

The Secretary then read the Annual Report for the year ending April 30th, 1880.

ANNUAL REPORT.

In presenting this report the Council has pleasure in congratulating the Association on its success during the past year. The professional and general interest in the affairs of the Association has surpassed the most sanguine expectations.

The last Annual Meeting having been held at the end of July, it has only been possible to arrange two District Meetings, one at Merton, on the 5th December last, and the other at Dewsbury, on the 19th March last. These Meetings were well attended, the works visited of high professional interest, the papers good, and the discussions well sustained.

The Council has pleasure in stating that since the last Annual Meeting thirty-four new Members have joined the Association, whilst it regrets to have to announce the death of four Members. Three Members have resigned, one Member had previously resigned but his name had been kept upon the books, and three Members having given up their official appointments have not sought to be re-enrolled. The number of Members on the roll of the Association at the close of the year was six Honorary Members

and 194 Ordinary Members, or in all 200 Members. This total has since been raised to 212 Members.

The Council trust the Members will make every effort to increase the roll of the Association by asking the various City and Borough Engineers and Local Board Surveyors under the various Municipal Authorities with whom they may come in contact to join the Association.

A Society founded on a basis such as is the case with this Association cannot but prove of the greatest benefit both directly and indirectly not only to its members, but likewise to the whole community.

In accordance with the rules of the Association the ballot lists were issued, with the result that the following gentlemen have been elected to the Council.

President.—A. W. Morant.

Vice-Presidents.—J. Allison, W. S. Till, R. Vawser.

Ordinary Members of Council.—W. B. Bryan, R. Davidson, C. Dunscombe, A. M. Fowler, S. Harper, T. Hewson, J. Lobley, A. W. Parry, J. Proctor, E. L. Stephens, T. C. Thorburn, W. H. White.

General Honorary Secretary.—C. Jones.

Treasurer.—Lewis Angell.

The Council considers the balance sheet appended hereto of a highly satisfactory nature, inasmuch as after paying off all arrears owing by the Association, the receipts have exceeded the expenditure by 149*l.* 3*s.* 11*d.* The statement of assets and liabilities likewise denotes that the Society is in a thoroughly sound financial position, there being a balance of assets over liabilities of 100*l.* 11*s.* 5*d.*, after making ample allowance for bad debts and depreciation in value of the 'Proceedings' in stock.

Mr. S. G. Gamble moved the adoption of the Report, which was seconded by Mr. R. Read and carried.

Mr. E. Pritchard moved, Mr. M. Hall seconded, and it was carried, that Messrs. A. W. Parry and W. H. White be appointed auditors for the ensuing year.

The following amendments to the Rules were brought forward as Council measures:—

Rule III.—"That the Association consist of Civil Engineers and Surveyors holding chief permanent appointments under the various Municipal Corporations or Sanitary Authorities within the control of the Local Government Board, and such Honorary Members as shall be elected by the Council. Members who cease to hold such appointments after the Annual Meeting of the Association in 1880

are eligible for re-election by the Council, but will be disqualified from holding any office, and from voting upon any matter affecting the Association."

Rule V.—"That the Council shall nominate one name for President, six for Vice-Presidents, one for Secretary, and twenty-two ordinary Members from which to elect the Council. Such nominations shall be printed and sent to each Member of the Association not less than fourteen days previous to the Annual Meeting. Every Member shall be entitled to vote for or erase any of such nominations, or substitute other names, subject in all cases to the limits of Rule IV., and return the same within seven days from the date of issue. Such ballot papers shall be examined in London by the President, Secretaries, and two scrutineers appointed at the previous Annual Meeting, or by any two of the aforesaid Members."

The adoption of the alterations to the rules having been moved by Mr. J. Allison, and seconded by Mr. A. W. Parry, they were fully discussed, with the result that the following amendment, proposed by Mr. J. P. Spencer, and seconded by Mr. E. Knowles, was carried:—

"That in the opinion of this Meeting it is not desirable to pass resolutions of so much importance without the consideration of the whole of the Members of the Association, and that to allow of this opportunity the proposed alterations in Rules be printed and distributed to each Member, and the Resolution be postponed to the next Annual Meeting."

Mr. E. Pritchard then said that the most agreeable part of his duty had arrived, inasmuch as he had to thank the Members for their great kindness to him during the time he had had the honour of representing the Association as President, and to inform them that in his successor, Mr. Morant, who had been unanimously elected President for the ensuing year, they had a gentleman who was gracing the Association by accepting the highest honour it was in their power to offer him.

Mr. A. W. Morant, Borough Engineer of Leeds, having taken the chair, thanked the retiring President for the manner in which he had been pleased to speak of him and the Members for having elected him President, and moved that a vote of thanks be passed to Mr. E. Pritchard for his services to the Association during his term of office, which was carried unanimously.

Mr. C. Jones, Hon. Sec., announced that the next Annual Meeting would be held at Birmingham.

The general business having been here concluded, the President delivered his inaugural address.*

Chas. Jones, *Hon. Sec.*
Graham Smith, *Secretary.*

* This Address, and the other papers read at the Meeting, will be found at the end of the volume.

Dr. STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDING APRIL 30TH, 1880. Cr.

RECEIPTS.	£	s.	d.
To Balance at Bank (October 23rd, 1879)	91	5	7
„ Entrance Fees	35	14	0
„ Subscriptions	164	17	0
„ Arrears	72	9	0
„ Subscriptions, &c., collected by Hon. Secretary	39	9	10
„ Private Sale of Pamphlets	10	7	3
„ Publisher's Sale of Proceedings	15	1	10
	£429	4	6
Balance, May 1st, 1880	£149	3	11

EXPENDITURE.	£	s.	d.
By Wolverhampton Meeting, April 1878	4	17	6
„ Derby Meeting, February 1879	12	11	9
„ Annual Meeting, July 1879	8	2	8
„ Merton Meeting, December 1879	3	3	0
„ Dewsbury Meeting, March 1880	5	11	4
„ Transcribing Notes, vol. i.	12	0	0
„ Messrs. Clowes and Sons, Printing vol. iii. (balance of account)	28	5	6
„ Messrs. Clowes and Sons, Printing vol. iv.	109	18	6
„ „ Cook and Hammond, Printing Circulars	10	7	6
„ „ Potter and Co., Subscription Ledger	1	8	6
„ Petty Cash—Stationery, &c.	19	0	8
Postage, General	5	17	0
„ Circulars	13	12	0
„ Secretary, including use of Offices, Clerk's Services, and Travelling Expenses	45	0	0
„ Bank Charges		4	8
„ Balance at Bank	149	3	11
	£429	4	6

STATEMENT OF ASSETS AND LIABILITIES, APRIL 30TH, 1880.

LIABILITIES.	£	s.	d.
To Printing vol. v.	65	8	0
„ Estimated Liability on vol. vi.	35	0	0
„ Outstanding Accounts (estimated)	9	0	0
„ Balance	100	11	5
	£209	19	5

ASSETS.	£ s. d.	£	s.	d
By Balance at Bankers		149	3	11
„ Subscriptions in Arrear	64 1 0			
„ „ less 50 per cent. bad and doubtful	32 0 6	32	0	6
„ Proceedings in Stock	57 10 0			
„ „ less 50 per cent.	28 15 0	28	15	0
		£209	19	5
Balance, May 1st, 1880		£100	11	5

Examined and found correct,

R. VAWSER, J. LOBLEY, } *Auditors.*

CHAS. JONES, *Hon. Secretary.*
GRAHAM SMITH, *Secretary.*

ANNUAL MEETING AT LONDON,

July 31 and August 1, 1879.

SLUICES AND PENSTOCKS.

By H. O. SMITH.

The sluice and penstock figure somewhat largely in works of sewerage, irrigation, and water supply, which are demanding at the present time a considerable share of attention. The aim in this paper will be to call attention to a few leading features in design and construction, not with a view of introducing anything novel, but with the idea of eliciting by discussion facts based upon actual experience.

The author will simply refer to the ordinary sluice-door commonly used in irrigation and works of sewage disposal, and to the penstock employed most frequently in works of sewer construction, and will exclude the sluice-valve, reservoir valve, flushing gate, tide valve, &c., as being types far too numerous in design to admit of more than a passing reference.

Sluice-door.—The sluice-door is commonly constructed of wood, while the side grooves and sill are formed of either wood, stone, brickwork, or iron. Where durability is desired cast-iron frames are best, however the author has found wooden frames preferable where an absolute watertight door is required. Fairly planed faces upon the doors and frames, and fairly cut grooves have produced all that can be desired. Cross tonguing to the doors is essential, and ledging is better than framing and clamping. The sill should not be grooved, as grit or other deposit therein is found frequently to prevent the door being "sent quite home," and a leak accordingly occurs.

A good example of the wooden sluice was employed by Mr. Baldwin Latham in the turbine chambers, at the Beddington sewage outfall, upon which works the author was engaged as resident engineer. The doors to the openings, 4 feet in the clear, were of 1¼-inch cross-tongued fir, and the frames 4½ inches ×

$4\frac{1}{2}$ inches oak with $1\frac{1}{2}$-inch grooves. These doors frequently stood with a 6-feet head of water above the sill, with only a trifling leakage. The most primitive fastening is probably that of the vertical arm, pierced with holes for the insertion of an iron or wood pin, which is also passed through the upper rail of the sluice frame. The rack and pinion, lever and quadrant, find considerable favour and are largely employed.

A very inexpensive sluice-door was designed and used by the author with very satisfactory results. It consists of a grooved fir frame $4\frac{1}{2}$ inches $\times$ $4\frac{1}{2}$ inches, with two oak top-rails $3\frac{1}{2}$ inches $\times$ $1\frac{1}{2}$ inch. The door is of $1\frac{1}{4}$-inch cross-tongued fir, with $1\frac{1}{2}$ inch $\times$ $1\frac{1}{2}$ inch wrought-iron braces let in flush.

Iron frames are made with angle-iron uprights $1\frac{1}{2}$ inch $\times$ $1\frac{1}{2}$ inch $\times$ $\frac{3}{8}$ inch, 3 feet 3 inches in length, and top rail of 2 inches $\times$ $\frac{1}{2}$ inch flat iron with forged bearing for gun-metal bushing. The author fitted this class of door a few months since and the cost delivered, including $1\frac{1}{4}$-inch diameter square threaded screw 2 feet long, and a gun-metal nut and bush, was 18*s.* 6*d.* each.

Good examples of wooden sluices may be seen on most of our English rivers and in irrigation works at home and abroad.

Penstock.—The penstock is largely employed in main sewers, either for the purpose of shutting off, penning up, diverting, or regulating a current of liquid. Tidal outfalls especially require them, as tide valves are unreliable and in many cases simply valueless. In heading up for flushing purposes the penstock is not so effective as the old stop-board or sluice-door which can be lifted suddenly.

The design and material of which penstocks are constructed depend upon their size and the work they are called upon to perform. With waterways of about 6 feet area and under, and small heads, the reservoir type in which the body of the valve is lifted by means of a capstan-headed nut working in a vertical screw, is a good and inexpensive design. The author has had several of these in almost daily use for some time. They are 3 feet in diameter, and are easily worked with one hand. The head of water is however small being never over 10 feet. Above this size it is advisable to have counter-balance weights, and the rack and worm-wheel motion is probably the best method for raising and lowering the door.

In the majority of instances with small as well as large sizes,

compound gearing is to be recommended, as by its means more power can be brought to bear both in screwing home and in commencing to open, and when working easy the key can be shifted from one spindle to the other and the door lifted or closed more rapidly.

The best method of facing penstocks is probably by gun-metal strips with planed faces both in the door and frame and fitted with wedges and adjusting screws.*

DISCUSSION.

Mr. LOBLEY considered the subject useful and interesting, and hoped that it would be thoroughly discussed by the Members present. He had adopted the wooden sluice frame and door with an addition of a cast-iron frame of a U-shape built into the brickwork where there was a head of water of only 2 or 3 feet. The wooden frame was wedged into the cast-iron groove and could be removed whenever it required renewing so that the only fixture was the cast iron.

Mr. GRAHAM SMITH said that timber sluice valves had been employed at the Liverpool docks with heads of water exceeding 30 feet since the formation of those docks. They were made of balks of timber bolted together without frames and bore against granite faces, frames of every description being dispensed with. They were entirely satisfactory and he was inclined to look upon cast-iron frames and gun-metal facings as unnecessary mechanical refinements very liable to get out of order, and involving considerable costs for repairs and maintenance. He was surprised to find Government officials and leading engineers adopting them in dock works. The sluice valves or clough paddles as they were called were at one time constructed in oak, but as the *Limnoria terebrans* was found to attack this timber greenheart had been substituted for many years past with the result that the life of these paddles up to the present time had not been determined.

Mr. LEMON had used the various types of penstocks brought forward in the paper, and his experience was that cast iron very quickly deteriorated in sewage water. He had put up cast-iron penstocks in 1867, and in less than ten years the cast iron was reduced to the consistency of plumbago. He found that where the

* The paper was illustrated with several diagrams of sluices and penstocks, which it has been thought unnecessary to reproduce.

worm rack was employed the valves did not remain watertight when the préssure was on the reverse side. The racks became stopped up with rags and other substances, and he therefore adopted the ordinary screw entirely covered from the action of the sewage and he found it to give much better results.

Mr. Ellice-Clark inquired if the cast iron was subject to the action of salt water?

Mr. Lemon replied no.

Mr. Morant said that there was no doubt but that cast iron was rendered like plumbago by salt water, and that there would be a back flow of salt water at Southampton.

Mr. Vawser had used wooden sluices, and found that a shrinkage of the timber took place, and that there was a difficulty in drawing them after an interval of two or three weeks. He had seen a very simple arrangement in which the frame was made wedge-shaped. This much facilitated the drawing, as immediately the door was moved it was quite free.

Mr. Lemon thought that the plan just mentioned was the same as the "tail wedge."

Mr. White had heard that where gun metal was brought into contact with cast iron a galvanic action was set up, and asked if any member could give information on this point.

Mr. Deacon (President) had never known galvanic action to take place between cast iron and cast brass in ordinary water, and he had never used it for sewage. With brass of very small dimensions the case was different. Brass wire in contact with cast iron deteriorated very rapidly from galvanic action.

Mr. H. O. Smith in reply stated that his object in introducing the wooden sluice-valve was to draw attention to an inexpensive type. Cast iron being very moderate in price at the present time he thought that now was the time to purchase cast-iron sluice-valves. He was unable to say whether galvanic action would be set up between cast iron and gun-metal in sewage.

The President in summing up the discussion thanked Mr. Smith for his practical paper, and expressed a hope that further papers on similar subjects would be forthcoming as it was most desirable that the Members of the Association should know each other's experience.

ANNUAL MEETING AT LONDON,

July 31 and August 1, 1879.

ELECTRIC LIGHTING, AND ITS APPLICATION TO PUBLIC ILLUMINATION BY MUNICIPAL AND OTHER BODIES.

By JAMES N. SHOOLBRED, B.A., M. Inst. C.E.

A Select Committee of the House of Commons recently, after a long and careful inquiry, presented a Report, in which certain recommendations were made as to the legal powers which in their opinion should be granted to municipal corporations and to other local authorities for the purposes of illumination by electricity. It may not, therefore, be out of place, before an Association composed of members most of whom have to deal with the question of electric lighting, in its application at least, to make a few observations upon that branch of the illumination which is of a public character; not with a view in any way to comment upon or to controvert the Parliamentary Report just mentioned, but rather to amplify or to supplement in some particulars the scientific evidence which was presented to the Select Committee.

It must not be supposed that the following remarks pretend in any way to treat the subject of public illumination by electricity in its entirety; they refer merely to a few points in its practical application, which fall rather within the province of the engineer than of the electrician. Indeed, it is here assumed that the scientific knowledge of the latter has been, or is, available in the choice of the electrical machine and lamps, and also in the judicious arrangement of the several parts; so as to obtain the maximum of good effect, electrically, according to the conditions of each case.

Only those methods of producing the electric light will be here referred to which have already been in actual operation, and which have stood the test of practical application; such as the Siemens, the Gramme, the Jablochkoff, the Wilde, and others similarly well

known. The details of the electric machines and other parts, constituting the features of these several systems, having been very fully described and explained in other available ways, are assumed to be familiar to the members.

The duties of municipal and other local authorities in matters of public illumination naturally divide the subject into two—1st, the exterior illumination of streets and of large open spaces; 2nd, the interior lighting of large halls, of markets, and of buildings of a similar class.

As the conditions which occur in these two classes are very varied, it will be best to commence by pointing out the results of actual working, together with the first cost, of some of the different systems for the production of the electric light; so as to be able to select the one which is likely to afford in each case the most effective, and therefore the most economical, and the proper solution, first for the creation of the light, and second for its due distribution. Furthermore, in the consideration of interior illumination a few words must necessarily be added upon the sanitary aspect caused by the use of the electric light.

An illumination by electricity may be effected either by a series of large lights, each the single output of an electric machine; or by a number, each of smaller dimensions, but all emanating from a single electric machine. To obtain such a nice balance as to give the exact amount of light, not too much nor too little, and so as to be equally distributed over the entire space to be illuminated, and yet to effect this in the most economical way, working expenses and first outlay both considered, must be the conditions which will afford the proper solution in each case.

The consideration of the economical condition of these single-light machines, as against that of the many light ones, is, in fact, the discussion of the question of the divisibility of the electric light; about which so much is being said at the present time, and upon the solution of which depends very largely the future extension of electric lighting.

The conditions of expense, under which an establishment for electric lighting would be laid down, must necessarily vary very much according to locality, and with many other circumstances; and this must also be the case for the working expenses of the resultant illumination. Nevertheless, in order to form some approximate basis (though necessarily but a very rough one) for comparison between the efficiency of the several forms of electric

lighting, the following estimates have been prepared. In each case a complete establishment is allowed for; such as would appear to meet most cases, a covered site alone excepted.

The electric light systems selected as types are all well-known ones. Such as, 1st, the Gramme "A" machine feeding an ordinary "Serrin" lamp; 2nd, the Siemens "medium" machine with the small-sized Siemens lamp, generally corresponding to it; and 3rd, the system known as the "Jablochkoff," consisting of an "excitor" and of a "light" machine of the Gramme pattern, feeding a number of "Jablochkoff," or other candles. The two first-named belong to the class of single-light machines, and give off the electric current in a "continuous" direction; the third system represents the many-light machines, and therefore the divisibility of the electric current, which is there given off "alternating in direction." Estimates of establishments each for a different number of lights have been prepared, such as readily may occur in practice, so as to present the different advantages relatively of the several systems under the varied conditions.

The estimates of the "Gramme" many-light machines with "candles" are not however based upon their most recent type (where the "excitor" and the "light" portion are upon one shaft and form but one machine), as it is hardly known in practice yet. But as these last afford a greater number of light-centres each of lesser power for the same amount of motive power than do the older machines, the effect with them must be to render still more apparent the economy resulting from the division of the electric light in extended illuminations.

It must not be supposed that the selection of these three electric light systems, as types, is intended as a proof of their superiority over other systems, such as the Lontin, the Wallace-Farmer, the De Meritens, the Wilde, the Werdermann, &c. It merely implies that, as owing to space a selection had necessarily to be made, the above have been chosen as being widely known by reputation, and about which much reliable information could be obtained.

In the following estimates, the hourly working of the gas engine per indicated horse-power has been taken at 1*d.*, which equals 22 cubic feet of gas at 3*s.* 9*d.* per thousand, a result borne out by careful experiments of the author and of others. With the steam-engine the hourly expense per indicated horse-power is placed at ½*d.*, viz. 6 lbs. of coal at 15*s.* 6*d.* per ton, and including lighting up.

COMPARATIVE ESTIMATES OF FIRST OUTLAY, AND OF WORKING EXPENSES OF SOME SYSTEMS OF ELECTRIC LIGHTING.

Gramme Single-Light "A" Machine with Serrin Lamp.

First Outlay.

One Light.	£	Two Lights.	£	Three Lights.	£	Five Lights.	£
1 "A" machine	75	2 machines ..	150	4 machines ..	300	6 machines ..	450
2 Serrin lamps	35	3 lamps	51	4 lamps	68	6 lamps	102
200 yards cable	10	400 yards cable	20	600 yards cable	30	1000 yards cable	50
1 lantern and sundries ..	10	2 lanterns, &c.	20	3 lanterns, &c.	30	5 lanterns, &c.	50
Fitting and fixing	10	Fixing	19	Fixing	22	Fixing	38
	140		260		450		690
3½ H.P. Otto gas engine	174	8 H.P. Otto gas engine	256	8 H.P. Otto gas engine	256	8 H.P. semi-portable steam engine and boiler	220
Carriage, fitting, &c.	16	Carriage and fixing	19	Carriage and fixing	19	Carriage and fixing	25
	£330		£535		£725		£935

Working Expenses per Hour.

One Light.	s. d.	Two Lights.	s. d.	Three Lights.	s. d.	Five Lights.	s. d.
Gas (1*d.* per Ind. H.P.)	0 5	Gas	0 8	Gas	1 0	Coal ½*d.* per Ind. H.P.	0 7
Oil, &c. ..	0 1½	Oil, &c.	0 3	Oil, &c.	0 3	Wood, oil, &c.	0 4
Engineman ..	0 9	Engineman ..	0 9	Engineman ..	0 9	Engineman and fireman	1 3
Carbons ..	0 2½	Carbons	0 5	Carbons	0 7	Carbons	0 10
	1 6		2 1		2 7		3 0

If an average of five hours' lighting takes place for 300 days during the year, or 1500 hours altogether, then the total expense of the above illuminations would severally be—

Working Expenses per 1500 Hours.

		One Light.	Two Lights.	Three Lights.	Five Lights.
		£	£	£	£
Motive power and light		113	156	194	225
Interest and depreciation at 10 per cent. on capital		33	54	73	94
Everything included	Total per annum ..	146	210	267	319
		s. d.	s. d.	s. d.	d.
	Or, Per light per hour	1 11·4	1 4·8	1 2·2	10·2
		£	£	£	£
Motive power not included	Total per annum, including interest ..	35	64	95	144
		Pence.	Pence.	Pence.	Pence.
	Or, Per light per hour	5·6	5·2	5·0	4·6

SIEMENS' SINGLE-LIGHT "MEDIUM"-SIZE MACHINE, WITH SIEMENS' SMALL-SIZE LAMP.

First Outlay.

One Light.	£	Two Lights.	£	Three Lights.	£	Five Lights.	£
1 "Medium" machine ..	115	2 machines ..	230	4 machines ..	460	6 machines ..	690
2 Siemens lamps	30	3 lamps	45	4 lamps	60	6 lamps	100
200 yards cable	10	400 yards cable	20	600 yards cable	30	1000 yards cable	50
1 lantern and sundries ..	10	2 lanterns, &c.	20	3 lanterns, &c.	40	5 lanterns and sundries ..	60
Fitting and fixing	10	Fixing	20	Fixing and fitting	25	Fixing and fitting	40
	175		335		615		940
3½ H.P. "Otto" gas engine ..	174	8 H.P. "Otto" gas engine ..	256	6 H.P. steam engine	200	8 H.P. steam engine	220
Fixed and fitted	16	Fixed and fitted	20	Fixing, carriage, &c.	20	Fixing, carriage, &c.	25
	£365		£611		£835		£1185

Working Expenses per Hour.

	s.	d.		s.	d.		s.	d.		s.	d.
Gas (1*d.* per Ind. H.P.)	0	6	Gas	0	10	Coal (½*d.* per Ind. H.P.)	0	8	Coal	0	10
Oil, &c. ..	0	1½	Oil, &c.	0	3	Wood, oil, &c.	0	3	Wood, oil, &c.	0	4
Engineman	0	9	Engineman ..	0	9	Engineman ..	0	9	Engineman ..	0	9
Carbons ..	0	3	Carbons	0	6	Fireman ..	0	6	Fireman ..	0	6
						Carbons	0	8	Carbons	1	4
	1	7½		2	4		2	10		3	9

Working Expenses for 1500 Hours.

		One Light.	Two Lights.	Three Lights.	Five Lights.
		£	£	£	£
Motive power, &c.		122	175	213	281
Interest and depreciation in capital at 10 per cent.		37	61	84	119
Everything included	Total per annum ..	159	236	297	400
	Or, Per light per hour	s. d. 2 1·4	s. d. 1 6·8	s. d. 1 3·84	s. d. 1 0·8
Motive power not included	Total per annum, including interest ..	£ 43	£ 78	£ 118	£ 189
	Or, Per light per hour	Pence. 6·9	Pence. 6·2	Pence. 6·3	Pence. 6·0

GRAMME "MANY-LIGHT" MACHINES, WITH "CANDLES" (JABLOCHKOFF, OR OTHERS).

First Outlay.

Six Lights.	£	Twenty Lights.	£
1 "6-light" machine and "Excitor"	200	1 "20-light" machine and "Excitor"	420
6 lamps, &c.	70	20 lamps, &c.	220
Cable	20	Cable	250
Fixing, &c.	10	Fixing, &c.	20
	300		910
Gas engine, 8 H.P.	256	Steam engine, 8 H.P.	220
Fixed complete	20	Fixed complete	25
	£576		£1155

Hourly Working Expenses.

Six Lights.	s.	d.	Twenty Lights.	s.	d.
Gas (at 1*d.* per Ind. H.P.) ..	0	8	Coal (½*d.* per Ind. H.P.)	1	0
Oil, &c.	0	3	Wood, oil, &c.	0	5
Engineman	0	9	Engineman and stoker	1	6
"Candles" at 2*d.*	1	0	"Candles"	3	4
	2	8		6	3

At the present price of Jablochkoff candles, their cost alone in the two cases would be 1*s.* 10½*d.* and 6*s.* 3*d.* respectively; a charge greatly in excess of the true value, as evidenced by that of other "candles," the cost of which has consequently been taken.

The expense of the above lights for 1500 hours per annum, as in the preceding cases, would be—

		Six Lights.	Twenty Lights.
		£	£
Motive power and light		181	406
Interest and depreciation at 10 per cent. on capital		58	116
Everything included	Total per annum ..	239	522
	Or, Per light per hour	Pence. 6·4	Pence. 4·2
Motive power not included	Total per annum, including interest ..	£ 93	£ 291
	Or, Per light per hour	Pence. 2·5	Pence. 2·3

With regard to the preceding examples of their cost, it must be remarked in the case of one light or even of two lights, on either the Gramme or the Siemens principle, it would be very seldom that a complete establishment (i. e. including a special motor, and the consequent expense of an engineman for this only) would have to be provided; and, that if a share of these expenses were borne either by other electric lights or by other duties, the diminution in the apparent cost both as to capital and as to working expenses of the one or two electric lights would be very considerable.

Again, as to what is generally termed the "Jablochkoff" system. The only part of it, however, to which the term can properly be applied is the "candle" which bears that name; and to the extravagant price at present put upon it, as will be seen by the figures given, is due by far the main item of working expense with that system proper.

The above example, though under the name of the Jablochkoff system, may be taken as a type of the division of the electric current in the same way that the Gramme, or the Siemens, is of the undivided current. It should be borne in mind that for the electric machine used (the double Gramme), an "Alliance," or a "Meritens," or a "Wilde," &c., might have been used; and also, that instead of a Jablochkoff "candle," one of the same class of lights, such as the "Wilde" or the "Meritens," might have been substituted. The item of "candle" expenses by the substitution of either of the last named for the Jablochkoff would, it is understood, be reduced by nearly one-half; and the resultant effect upon the total expense of the light would be considerable.

The foregoing figures may serve to give a rough idea as to the actual cost of the production of the three forms of light; but another element which should be taken into consideration, in order to arrive at the real economic value of each light, is its illuminating utility.

To endeavour to illustrate this, suppose the actual available luminous intensity, measured on the horizontal, to be 3000 standard sperm candles for the Gramme, 4000 for the Siemens, and 400 for the Jablochkoff; with the lamps of the first two named placed at 21 feet above the pavement, and the last one at 15 feet, and each light provided with a suitable overhead reflector. Then, with the several lights, the circular area of pavement, the circumference of which would represent an equal degree of illumination, might be taken as a measure of comparison of the relative

illuminating utility of each light. If for example the factor 0·15 be taken as the minimum of illumination; a figure given by the President of this Association as an illustration in his evidence before the Parliamentary Select Committee "On Lighting by Electricity." This figure being the quotient resulting from the division of the illuminating power in standard candles of the light-centre by the square of the distance in yards from that centre to the point of minimum illumination on the pavement. This factor, it is understood, means the equivalent of a light of one candle at a distance of 2½ yards from the light-centre.

In the above cases, and under the conditions of position and height of the several lights as suggested, this factor 0·15 would represent

	Illuminating Power. Standard Candles.	Radius. Yards.	Area Illuminated. Square Yards.
Jablochkoff ..	400	52	8,332
Gramme	3000	142	62,901
Siemens	4000	163	83,982

Thus while the relative intensities of the light-centres bear to each other (approximatively) the proportion of 1 : 7½ : : 10, and the distances of minimum illumination that of 1 : 2¾ : : 3½, yet the illuminated areas (being as the squares of the diameters) are as the light-centres respectively.

Besides the relative cost and the luminous utility of a particular light, there is a third quality which must be taken into consideration; viz. its fitness for the locality to be illuminated. Thus, for instance, to make use generally in street lighting of single lights of large power, using regulator lamps, such as the Gramme or the Siemens just described, would be, except at central "refuges," to waste a deal of their light; as the luminous intensity supplied by a "candle" suffices for the breadth of most of the wide streets where electric lighting would be used. While again in large open spaces such as squares, the more extended area commanded by the single lights would give them a preponderating value over the more moderate sphere of the "candle"-lights.

Again the very great distance to which the current from the "candle"-supplying machines can be transmitted through comparatively small cables, as evidenced by the results afforded in connection with the electric lighting on the Thames Embankment, in London, must give that form of electric light an advantage, in long streets,

over the single-light regulator type. It has been shown on the Embankment, that from one centre an area having a diameter of 4 miles can readily be commanded, without any apparent loss in the luminous intensity of the more distant lights. Nothing at all approaching any such distance has ever been attempted with "regulator" lights, so far as is known to the author; nor is it probable that it could be effected. The low tension and large quantity of the electric current, with the latter class of lights, necessitating conducting cables of much larger section, would probably prove unable, owing to loss, to be transmitted to anything like the distance, which the high tension of the current supplied to the "candles" is found readily to traverse.

For the illumination of the interiors of large buildings the choice of the particular form of light must depend very much upon the cubical space to be lighted up; though of course the form and use of the building must be taken largely into consideration. For instance, the Royal Albert Hall, with its 150 feet from the "velarium"-screen to the arena, naturally lends itself to the use of large lights; which have the power to transmit their illumination through this long distance. While again a room only 20 feet or so in height would be more suitable to the use of a "candle"-light; if not even to the more moderate-sized semi-incandescent light, such as the Werdermann light, which is being tried with apparent success in the small Art Library of the South Kensington Museum.

In the illumination of interiors one chief point to be avoided would appear to be to have but one light-centre; as very marked and very objectionable shadows are the result. Whereas with several light-centres they are to a great extent avoided; and also to a certain degree any flickering from one luminary is somewhat neutralized by the rays from its neighbour. Not merely should any direct exposure of the bright luminous point to the eyes of the spectators be avoided, by suitable protection of glass or otherwise, but even direct projection or reflection of the luminous rays down on to the spectators should be dispensed with where practicable. Double reflection, on to and from the ceiling and adjacent walls, thereby more fully diffusing the light, distributing it and rendering it like to sunlight, while at the same time toning it down and neutralizing in a great measure many of its irregularities, is so far as the author's experience goes by far the most agreeable mode of illuminating interiors with the electric light.

Into the consideration of the illumination of interiors there

enters another question, apart altogether from the efficiency of the light, and that is, its effect upon the surrounding atmosphere from a sanitary point of view. In this respect its effect is twofold, viz. 1st, the amount of vitiation caused by noxious products and vapours formed during combustion; and, 2ndly, the quantity of heat given off to the surrounding air.

The unpleasant and unwholesome effects caused by gas illumination on both of these heads, particularly where the lights are naked, are so well known, that the possibility of the substitution of that illuminant in crowded rooms by the electric light has been welcomed with pleasure in many quarters; and the amelioration accepted as an accomplished fact. Some months ago, however, serious doubts were raised on one of the above points, that of noxious emanations, by a chemist of great promise, the late Mr. Thomas Wills; whose sudden and premature death at the outset of what promised to be a very brilliant and useful career is much to be deplored. He announced at the Chemical Society towards the close of last year, that from experiments he had carried out he had reason to suppose, that nitrous oxides were given off in considerable quantity by the electric light from carbon electrodes, due to the high temperature of the electric arc. It is, however, credibly reported, that on further investigation he found before his death the amount of the noxious emanations to be less than he had previously supposed. However the fact still remained that gases of this nature were given off, and it was thought well to inquire somewhat into the matter.

It is with much pleasure, that the author is enabled to lay before the Association the results of some experiments made by Mr. F. J. Evans, of the Gaslight and Coke Company, which he has kindly prepared specially for this occasion; the results of which, contained in the table annexed, have been analyzed by Mr. McMinn, a chemist of much experience in the employ of the same company.

The experiments, at which the author was present by the invitation of Mr. Evans, were carried out in July of this year, at the premises in Horseferry Road, Westminster, of the Gaslight and Coke Company. An 8-horse power "Otto" gas engine actuates by means of overhead shafting a small-sized Siemens electric machine (1200 candles nominal); the current of which is supplied to a small-sized Siemens lamp. The number of revolutions of the electric machine during the experiments was 1000 per minute.

Estimation of Nitrogenous Compounds and Carbonic Acid Produced by the "Electric Lamp" in One Hour, and Arrested by means of a Solution of Potash.

(The Second Experiment was of thirty minutes' duration, but the results are given as quantities per hour.)

First Experiment.	Nitrogenous Compounds.		
	Nitrogen equal to	Nitrous Acid.	
	Grains.	Grains.	Cubic inches.
First bottle	0·182	0·613	1·214
Second ditto	0·106	0·357	0·707
Third ditto	0·152	0·511	1·012
Total	0·440	1·481	2·933

First Experiment.	Carbonic Acid.	
	Grains.	Cubic inches.
First bottle	35·5	75·1
Second ditto	33·0	69·8
Third ditto	29·6	63·0
Total	98·1	207·9

Second Experiment.	Nitrogenous Compounds.		
	Nitrogen equal to	Nitrous Acid.	
	Grains.	Grains.	Cubic inches.
First bottle	0·2280	0·766	1·512
Second bottle	0·4890	1·635	3·238
Third ditto	0·7924	2·656	5·260
Total	1·5094	5·057	10·010

Second Experiment.	Carbonic Acid.	
	Grains.	Cubic inches.
First bottle	72·8	154·0
Second ditto	62·0	131·1
Third ditto	42·5	89·9
Fourth, containing lime water	0·9	1·7
Total	178·2	376·7

July 18, 1879. A. C. McMinn.

The luminous arc and the adjacent portions of the carbons were placed in a closed copper-framed square box, 6 inches each way, with the sides of talc. In one of the sides of the box, near to the top, was placed the end of a tube; the other extremity of which was in communication with the air-pump of a horizontal engine, in

an adjacent room, and used for pumping water and other purposes. Upon the exhaust pipe, thus constructed to carry off the products of the electric light, were placed close to the light a series of four pint bottles; through all of which the products were compelled to pass. The first three bottles (referred to in the table in their order from the electric light) contained a solution of caustic potash, each bottle having about 100 grains of potash to half a pint of water; the fourth bottle consisted of "lime water." The carbons employed for the electric light were ½ inch in diameter, and each hour's burning (the normal duration of each experiment) consumed about 2¾ inches—1 inch of the negative carbon, and 1¾ inches of the positive; or by weight 214 grains.

The result analytically of each of the two experiments is set forth by Mr. McMinn in his table. There is a very considerable difference between them, both the nitrous acid and the carbonic acid being much more in the second experiment than in the first. Mr. Evans considers, that this is partly due to the increased current of air through the apparatus in the second case. The experiments do not pretend to have been carried out in such a way, as to give more than an approximate result. Indeed, Mr. Evans does not consider them in any way conclusive, and intends to repeat them.

The results are however sufficient to enable one roughly to estimate the comparative value of the noxious emanations from the electric light and from gas illumination. The deleterious gas in the former case was nitrous acid, and in the latter sulphurous acid; both of which being objectionable in somewhat about the same degree, it becomes a question rather of the relative quantities of each in the respective illuminations.

Take the nitrous acid total in the second experiment, the larger of the two, 5 grains; the result of the production of a light of say 1000 standard candles during one hour.

In the combustion of gas from 10 to 20 grains of sulphur per 100 cube feet of gas is, it is understood, a good result. Say 10 grains of sulphur, or 20 grains of sulphurous acid per 100 cube feet of gas; the illuminating value of which would be 400 standard candles per hour. Therefore an illumination by gas of 1000 candles per hour would require the consumption of 250 cube feet of gas; giving off 50 grains of sulphurous acid; as against the 5 grains of nitrous acid arising from the electric light.

Suppose however that in actual illumination the 1000-candle

electric light was found only to replace 20 gas jets, of 3·5 cube feet each, and yielding a total light of 200 candles. This would give a total hourly consumption of 70 cube feet of gas yielding 14 grains of sulphurous acid.

The small amount of the carbonic acid emanating from the combustion of the electric light may be gathered from that stated in the second experiment; the larger amount of the two. The quantity is given as 377 cube inches, not quite ¼ cube foot, as the result of one hour's burning. When it is borne in mind that *each person* is supposed to give off about ½ cube foot per hour, or double the above emanation, an idea of its baneful character may be formed.

In the further continuation of the Sanitary aspect resultant from illumination, next occurs the question of the amount of heat developed.

The evidence of a very distinguished electrician, Sir William Thomson, given before the Select Committee on "Lighting by Electricity" gives some clue, at least theoretically, to the relative amounts of heat given off by illumination by electricity and by gas. Sir William Thomson stated that the energy which is actually used in the electric arc is about 1 horse-power per 1600 candle-power; and that with gas 1 horse-power produced only 12 candle-power. This would indicate an expenditure of 133 times more mechanical energy per candle-power with gas than with electricity. Or if converted into heat that 213·7 heat units (Joule) would be developed during the hourly maintenance of 1 candle-light by gas, as against 1·6 heat units per candle by electricity. This would, taking each cube foot of gas per hour to be of 4 standard candle-power, cause each cube foot of gas to give off 854·8 heat units per hour.*

This calculation is nearly confirmed by the experiments made in connection with lighting and heating by gas in the City of Paris; viz. 1 cube metre of gas giving 8008 calories.† This would cause the cube foot of gas to give off 898·8 heat units per hour. The mean of these two values would give 877 heat units per hour.

Taking the last-named figure as the result per horse-power,

* With the heat unit of 772 foot-pounds (Joule), and the horse-power at 32,000 foot-pounds per minute, or 1,980,000 per hour, the thermal equivalent of one horse-power per hour is 2564 heat units.

† See 'Formulaire de l'Ingénieur-constructeur,' par Ch. Armengand jeune, 1865.

and comparing it with the electric light systems already referred to, viz. the Jablochkoff, the Gramme, and the Siemens: then on the assumption that the total horse-power absorbed by each of them is respectively 1, 2·5, and 3 horse-power, of which one-half is absorbed in the electric arc (though it actually must be less), the comparative amounts of heat given off by each, and that of a gas illumination which may be taken in practice as the equivalent of each, would stand thus:—

	Electric Illumination.			Gas Illumination.		Ratio of Heat Units. Gas to Electricity.
	Light in Standard candles.	H.P. in Arc.	Heat Units.	Jets of 3·5 c. f. each.	Heat Units.	
Jablochkoff	400	0·5	1282	10	30,625	24 to 1
Gramme	3000	1·25	3205	30	92,085	28 to 1
Siemens	4000	1·5	3846	40	122,780	32 to 1

Turning to the actual effect of the two illuminations, by gas and by electricity, when tried simultaneously, the effects experienced at the Art Library of the South Kensington Museum may be quoted. One large room, in all 54 feet by 54 feet by about 18 feet high, is divided down the centre, so as to form practically two rooms. The gas illumination in each room is effected by means of fifteen argand burners, arranged in threes, suspended from the ceiling, and brought down to about 10 feet from the ground. Three Werdermann lamps in each room on standards about 9 feet high are occasionally used in the evening in place of the gas. The effect on a summer's evening has been most marked, and the contrast rendered still more so by the two illuminations being used alternately on the same evening, the relief obtained by the use of the electric lighting from the increase in temperature caused by the gas being remarkable and speedily felt.

Nor is the great disproportion between the heat evolved by the electric arc and by the combustion of coal gas to be wondered at, when the composition of the latter is taken into consideration; notwithstanding even the very high temperature of the electric arc Professor Bunsen,* in his analysis of Manchester cannel gas, found that while the illuminating components only represented 6·5 per cent. of its volume, the non-illuminating heat-producers formed 87 per cent. Besides in the amount of heat evolved respectively

* 'Gasometry,' by R. Bunsen, translated by H. E. Roscoe, 1857.

this disproportion is still further considerably increased (chiefly owing to the heat-producing qualities of the hydrogen and of the marsh gas).

Then again there must be borne in mind the very small amount of the surrounding air, which can have access to the small and single electric arc, as against the very much larger area of flame presented by each of the many gas-jets. The disproportion between the heating surfaces in the cases of illumination just mentioned would probably amount to 200 times.

Illumination by electricity having now come within the province of the Municipal Engineer, as evidenced by the Acts of the present session of Parliament, the author has in response to the request of the President ventured to place the foregoing remarks upon the subject before the Members of the Association.

The Author then explained several diagrams illustrating the paper, more particularly one of the illuminating and of the horse-power absorbed in the Jablochkoff lights on the Thames Embankment.

DISCUSSION.

Mr. DEACON (President) remarked that the Jablochkoff candle was put down at 2*d.* per hour, and asked if Mons. Gaudet could say if that was a marketable price; and if not, what was the lowest price it could be sold at?

Mons. GAUDET: The Jablochkoff would cost 4½*d.*, and would last 1¾ hours.

The PRESIDENT: Then the price was 2½*d.* to 2¾*d.* per hour. He thought it quite unnecessary for Mr. Shoolbred to apologize for his paper. The subject of electric lighting would assuredly be brought home to many present in a much more direct manner than hitherto, and this paper and the discussion upon it would he believed be of great utility. He was glad to hear Mr. Shoolbred's last remark with regard to the electric lights on the Thames Embankment. A popular misapprehension had evidently existed on the subject. Persons judging by the newspaper reports were deluded into the idea that the length of a circuit could be enormously increased without loss. To obtain the highest economy it was necessary that what was called the external resistance, that is the resistance of the circuit exclusive of the dynamo-electric machine,

should bear a certain proportion to the total resistance; and if in the first installation the circuit was so short or the wire so thick that the external resistance bore a smaller proportion to the whole resistance, an increase of length would rather increase than diminish the efficiency until and only until the proper ratio was reached.

Mr. W. E. Ayrton thought that the way in which the light was used on the Thames Embankment was a good example of the extremely conservative character of the nation. The electric lamps had been used 20 feet above the ground without any reflectors the result being that 30 per cent. only was utilized, 50 per cent. of the whole being shut off by the globes and about half of the remainder going to the sky. The proper way was to have single very bright lights and two or three would be sufficient to illuminate a great area. If the lights were placed very high there would be no occasion for shades. There was never any necessity to shade the sun and why should there be any necessity to shade the electric light? Reflectors were being placed on the Embankment lights, but they were arranged like the reflectors of reading lamps and would simply throw the light to the ground just around the lamps, whereas they should be so arranged as to throw the light to a distance.

Mr. Bamber desired to speak to one point connected with the table comparing the Gramme machine working the Serrin lamp with the Siemens machine and lamp. That table appeared to show without further explanation, that the Siemens machine was the less economical of the two but it had been abundantly proved to be the more economical. Mr. Shoolbred had assumed that the Gramme machine referred to in the table was of only 3000 candle-power and the Siemens machine of 4000, and if the necessary correction for luminous power were made in the table the Siemens machine and lamp would cost 5·17 pence, against the gramme of 3000 candles 5·6 pence per equivalent light of 3000 candles per hour, showing that the Siemens machine was 10 per cent. more economical than the Gramme machine.

Mr. Ward quite agreed with what Mr. Ayrton had said as to the application of Jablochkoff candles on the Embankment. He had gone into the question of lighting Queen Victoria Street. The cost of the present system reckoning the gas at 3*s*. 6*d*. per 1000 feet must be 3*s*. 2*d*. per hour, the total lighting power being between 3000 and 4000 candles. The length being 372 yards,

three or four electric lights would be sufficient, and they could be put up and maintained at a cost of 2*s.* 6*d.* per hour, or 8*d.* less than the cost of gas, which would include the wages of two men. He thought Queen Victoria Street a very favourable place to try the large electric light. The elevation would be 40 or 50 feet, and if an experiment of that kind were made, it would demonstrate that the use of the electric light in that particular form was more economical than gas, not merely per unit of light, but absolutely. Extensive experiments with powerful electric lights were now being made at Chatham, and very interesting statistics would soon be obtained. Apart from the question of economy, he believed it was incontrovertible that the Gramme machine had produced a light larger than any other.

Mr. ANGELL was much interested in the valuable paper. It referred to the different qualities of the machines and their relative merits. He was pleased to hear that Queen Victoria Street could be lighted at less cost by electric light than by gas, as until proof was given to the various municipalities that as good an effect could be produced by electric light as by gas at less or the same cost they would not adopt it. We had heard of the great advantages of the electric light with respect to the deleterious gases, but the question of cost would he thought be more potent in our town councils.

Mr. PRITCHARD had been very much interested in the paper. On the point of cost he should like to know something more, and he believed the President had prepared a very able report, with various comparisons as to the cost of electric lighting and gas lighting. In Liverpool there was an electric light at a considerable altitude, and he should be glad to know if that had been found a favourable application.

Mr. LEMON was pleased to hear Mr. Ward's observations as they indicated some probability of the electric light coming into use for street lighting. He had found in the gas lighting of streets that the maximum distance at which lamps should be placed was about 60 yards, the average distance being about 40 yards. If with the electric light small print could be read at a distance of 100 yards, it was manifestly a great step in advance of good gas lighting. He understood Mr. Ward to say he should put four electric lights in Queen Victoria Street; he should like to know how many gas lights these would replace. He desired further to know whether municipal authorities could utilize for electric

lighting spare motive power employed for sewage and water pumping.

Mr. JERRAM believed he was the first to light up a large building with the Gramme machine in England; the Christmas before last, he displaced 120 gas lights and lighted up a hall with one machine. He visited London some time since, and saw the electric light at work in the Strand and on the Thames Embankment. He tried at each place an experiment by looking at his watch, with a view of ascertaining at what distance he could read the figures thereon, and found the light opposite the "Gaiety" enabled him to read them at a greater distance than did the other light. In some large workshops in France a large centre light was used with a system of reflectors which threw the light on to the wall, and from the wall it was diffused and thrown back to the work. Electric lights might be adopted at street crossings with great economy by placing them high up and using reflectors.

The PRESIDENT remarked that as Mr. Shoolbred had referred to his (the President's) evidence before the Select Committee on Electric Lighting, respecting standards of that lighting, he desired to make the matter a little more clear.

He had long been in the habit of comparing the lighting of different streets by the intensity of illumination of intermediate points between the lights: that intensity was evidently not necessarily proportional to the gross candle power, for if we halved the number of lights and doubled the intensity of each the gross candle power would remain the same, but the light half-way between any two would be reduced to about one half. It was obvious therefore that, altogether apart from the question of gross candle power in a given length of street, the distribution of the lights was a most important consideration; and when a new mode of lighting was likely to be introduced in which large lights were, per unit of light, so much more economical than small lights, the element referred to became of paramount importance. To determine the intensity of illumination at any point in a street it was only necessary to bear in mind that the intensity of light from any given source was directly proportional to the illuminating power of the light and inversely proportional to the square of the distance between the light and the point in question. If therefore on any street plan showing the lamps, a point intermediate between any two or more lamps were chosen, the illumination at that point might be repre-

sented by the sum of all the quotients obtained by dividing the illuminating power in standard candles of each lamp by the square of its distance in yards from the point in question. In a moderately well lighted street the figure thus obtained was ·15, which was nearly equal to the intensity of light from a standard candle at a distance of 2½ yards. At the junctions of many streets the intensity in the darkest intermediate places rose to ·3, equal to two standard candles about 2½ yards distant, or even higher. In making calculations as to the effect of different modes of lighting, it was quite necessary to employ some such method.

It was important however to remember that although the intensity of the light diminished almost exactly as the square of the distance when ordinary gas lamps or the Jablochkoff electric candles were used, the law was entirely altered when reflectors were employed. And this brought him to the consideration of one great advantage which electricity possessed over gas for illuminating purposes. Where as in the case of gas many small lights were employed the first cost of reflectors was relatively large, the smoke and other impurities of the gas soon dimmed them, rendered them comparatively useless, and greatly increased the cost of cleansing. From the same cause even the clear glass lanterns obstructed a large quantity of light. In the case of the electric light however the number of foci was relatively small, and the total cost of reflectors was also relatively small. Each focus was little more than a point of light, and could therefore be reflected with much greater accuracy than in the case of gas, while the products of combustion did not dim the surfaces of the reflectors or of the lanterns. He thought therefore that although reflection had not been largely adopted in connection with public gas lamps it would become an important element in public electric lamps.

The proportion of the light intercepted by the reflectors which could be thrown into useful directions depended upon a variety of conditions, and would vary according to the circumstances of each case, but it was large enough to recoup the extra cost abundantly in a short time.

The report which he had submitted to the Liverpool Corporation instituted a comparison between the actual cost of lighting the Avenue de l'Opéra in Paris by electricity and by gas, and the comparison was favourable to gas. But the low efficiency of the electric light arose from circumstances which were not inherent, and when the electric light was applied in the most

economical manner for the illumination of large open spaces the cost was he believed less than that of gas, while for the illumination of large symmetrical interiors the comparison was even more favourable to electricity.

One of the most favourably lighted interiors he had yet seen was the Albert Hall, where five Siemens electric lamps were hung near the top of the dome, from which the light passed through a cloud of gauze to the audience.

In the Picton Reading Room at Liverpool, a circular hall a hundred feet in diameter with a domed ceiling, he had obtained an excellent result with three electric lights of 3500 to 4000 candles each, grouped back to back in the centre at a height of about 20 feet. Below the lights was a temporary saucer of paper, to be replaced by a permanent saucer of ground glass five or six feet in diameter. All the upward rays passed from the naked light to the faintly tinted ceiling of the dome, and were reflected downwards, while the direct rays were diffused by the saucer, and were not unduly strong.

At the works of Messrs. Sautter, Lemmonier et Cie., in Paris, a long room full of the large frames of lens-grinding machines was most satisfactorily illuminated by a single electric lamp applied in a very rough-and-ready way. The lamp was hung some feet from the centre of the ceiling, and was entirely hidden by being placed in a large bucket. The rays which passed upwards struck two whitewashed boards so arranged as to reflect them to the opposite ends of the room. The walls and ceiling and frames of the machines were all whitewashed, and the shadows were less marked than on a sunshiny day.

APPENDIX.

Report of the Select Committee of the House of Commons upon Lighting by Electricity. June 13th, 1879.

The general nature of the electric light has been well explained in the evidence of Professor Tyndall, Sir William Thomson, Dr. Siemens, Dr. Hopkinson, and others. It is an evolution of scientific discovery which has been in active progress during the whole of this century. Essentially the electric light is produced by the transformation of energy either through chemical or mechanical means. The energy may be derived from a natural force as for instance a waterfall, or through combustion of a material in the cells of a voltaic battery, or of fuel in a furnace. The energy being converted into an electric current may be used to manifest electric lighting by passing between carbon points or by rendering incandescent solid bodies such as iridium. A remarkable feature of the electric light is that it produces a transformation of energy in a singularly complete manner. Thus the energy of one horse-power may be converted into gas-light, and yields a luminosity equal to 12 candle-power. But the same amount of energy transformed into electric light produces 1600 candle-power. It is not therefore surprising that while many practical witnesses see serious difficulties in the speedy adaptation of the electric light to useful purposes of illumination, the scientific witnesses see in this economy of force the means of great industrial development, and believe that in the future it is destined to take a leading part in public and private illumination. There is one point on which all witnesses concurred, that its use would produce little of that vitiated air which is largely formed by the products of combustion of ordinary illuminants.

Scientific witnesses also considered that in the future the electric current might be extensively used to transmit power as well as light to considerable distances, so that the power applied to mechanical purposes during the day might be made available for light during the night. Your committee only mention these opinions as showing the importance of allowing full development to a practical application of electricity, which is believed by competent witnesses to have future important bearings on industry.

So far as the practical application of the electric light has already gone, there seems to be no reason to doubt that it has established itself for lighthouse illumination and is fitted to illumine large symmetrical places such as squares, public halls, railway stations, and workshops. It is used in Paris for lighting shops which require a light by which different colours may be distinguished, and has recently been used in England for the same purpose with satisfactory

results. Many trials have been made for street illumination with greater or less success.

Compared with gas the economy for equal illumination does not yet appear to be conclusively established. Although in some cases the relative economy for equal candle-power is on the side of the electric light yet in other cases gas illumination of equal intensity has the advantage. Unquestionably the electric light has not made that progress which would enable it in its present condition to enter into general competition with gas for the ordinary purposes of domestic supply. In large establishments the motors necessary to produce the electric light may be readily provided, but so far as we have received evidence no system of central origin and distribution suitable to houses of moderate size has hitherto been established.

In considering how far the Legislature should intervene in the present condition of electric lighting, your Committee would observe generally, that in a system which is developing with remarkable rapidity it would be lamentable if there were any legislative restrictions calculated to interfere with that development. Your Committee however are not in a position to make recommendations for conditions, which may hereafter arise but at present do not exist, as to the distribution of electric currents for lighting private houses from a central source of power. No legislative powers are required to enable large establishments such as theatres, halls, or workshops to generate electricity for their own use.

If corporations and other local authorities have not power under existing statutes to take up streets and lay wires for street lighting or other public uses of the electric light your Committee think that ample power should be given them for this purpose. There seems to be some conflict of evidence as to whether the existing powers are sufficient or not. But even in regard to local authorities it would be necessary to impose restrictions upon placing the wires too near the telegraph wires used by the Post Office as the transmitting power of the latter would be injuriously affected by the too close proximity of the powerful electric currents needed for producing light.

Gas companies in the opinion of your Committee have no special claims to be considered as the future distributors of electric light. They possess no monopoly of lighting public streets or private houses beyond that which is given to them by their power of laying pipes in streets. Electric light committed to their care might have a slow development. Besides though gas companies are likely to benefit by the supply of gas to gas engines which are well suited as machines for producing electric light, the general processes of gas manufacture and supply are quite unlike those needed for the production of electricity as a motor or illuminant.

Your Committee however do not consider that the time has yet arrived to give general powers to private electric companies to break up the streets unless by consent of the local authorities. It is however desirable that local authorities should have power to give facilities to companies or private individuals to conduct experiments. When the progress of invention brings a demand for facilities to

transmit electricity as a source of power and light from a common centre for manufacturing and domestic purposes, then no doubt the public must receive compensating advantages for a monopoly of the use of the streets. As the time for this has not arrived your Committee do not enter into this subject further in detail than to say that in such a case it might be expedient to give to the Municipal Authority a preference during a limited period to control the distribution and use of the electric light, and failing their acceptance of such a preference that any monopoly given to a private company should be restricted to the short period required to remunerate them for the undertaking, with a reversionary right in the Municipal Authority to purchase the plant and machinery on easy terms. But at the present time your Committee do not consider that any further specific recommendation is necessary than that the local authorities should have full powers to use the electric light for purposes of public illumination, and that the Legislature should show its willingness, when the demand arises, to give all reasonable powers for the full development of electricity as a source of power and light.

ANNUAL MEETING AT LONDON,

July 31 and August 1, 1879.

THE SEPARATE SYSTEM OF TOWN DRAINAGE.

By LEWIS ANGELL, M. Inst. C.E., Past-President.

Until recently the general idea of a system of town sewerage was to collect drainage of every kind, surface and domestic, into the same conduit. Sewers were therefore made of large capacity, at great cost, and drainage of all kinds conducted to a common outfall. In the early part of the present century it was penal to discharge sewage into drains. It was laid down by Lord Chief Justice Holt "that every man should keep his dirt to himself." In the middle of the century it became penal *not* to discharge sewage into drains, consequently the nearest river became converted into a common open sewer. In this latter part of the century it is penal to discharge sewage into a river, consequently the necessity arises either before or after collection to separate the sewage from the water drainage, excepting where outfalls are in the sea. The author therefore submits that it is more economical to divert and separate surface waters from sewage in the first instance. One of the great difficulties of the purification of sewage, whether it be for irrigation or precipitation, is its bulk. Reduce the quantity, obtain concentration and uniformity, and the manipulation becomes easier. Most towns have their rivers or watercourses, to which short cuts can be made by comparatively inexpensive drains. Towns which have no sewers, in the modern acceptation of the term, have some sort of system of old drains and culverts through which, from time immemorial, the surface waters have been drained away; these old drains are unfitted from their gradients and sections to receive sewage, but in many and most instances the surface waters had better have remained in these old channels rather than be diverted into a new system of sewers. A small sectional area is sufficient for a uniformly small flow of sewage, but a large sectional area is

adopted to receive intermittent and variable volumes of surface drainage and storm waters. When the surface drainage can be diverted and divided at convenient points, and carried by short cuts to the nearest watercourse, the necessity for large and increasing sectional areas no longer exists, consequently there will be economy in the construction of the sewers, and great economy in the treatment of the sewage at the outfall; especially will this be the case where pumping is necessary.

Speaking in general terms the surface drainage of towns found its way into natural channels before the handsome pumping station down in the valley—the pride of the sanitary engineer—was built. The engineer improving on nature has diverted the surface drainage from its score or two of natural outfalls into his big "main sewer" discharging into the "well," from whence it has to be lifted again by machinery, most excellent for the purpose, but a still more excellent plan would have been to have "left well alone." Again when surface waters are thus collected and concentrated into given channels the inconveniences arising from the flooding of basements constantly arise, and where pumping engines have to be depended on still greater troubles occur.

In illustration the author has at the present moment two towns in which he is applying the separate system of drainage. The borough of Maidstone with a population of about 30,000, and the district of West Ham, Essex, with a population of 130,000. In Maidstone, which is a gravitating scheme, the author had the advantage of beginning at the beginning. The Medway runs through the centre of the town, with other streams at right angles thereto; old drains existed in parts of the town discharging directly into the river; for every street a duplicate system of drains was designed, viz. a deep drain for sewage, as part of a concentrating system, enlarging in sectional capacity onwards to the outfall, and a disjointed divided and unconnected series of drains carried directly into the river at convenient points for discharging surface waters, consequently the capacity of each system is reduced, a uniform flow of sewage is delivered into the tanks, and a tidal reservoir which was in this case necessary greatly reduced in capacity. Several of the existing drains which would not work into the sewage system are utilized as surface drains discharging by their old outlets into the river.

In the case of West Ham, a large system of sewers, with pumping engines, was constructed some eighteen years ago; the

main sewers are of large capacity and great length, but the conversion of rural into urban districts has caused large volumes of surface drainage, formerly absorbed by the land, ditches, &c., to flow quickly to the sewers, and thence to the distant pumps. Not only is the old pumping power quite unequal to emergencies, but the main outfall sewer although of great capacity no longer discharges storm waters with sufficient rapidity, consequently both the upper and lower levels are flooded. These large volumes of water ultimately reach the outfall only to be pumped up again into tanks and there treated chemically. The author has therefore designed a system of intercepting surface drains discharging at convenient points in the rivers so as to divert as much as possible of the rainfall from the sewers, and thus relieve the pumps and greatly reduce the volume to be treated at the tanks.

It may be urged that surface drainage is of advantage for flushing the sewers. The author secures and controls this advantage by penstock chambers connecting the two systems so that the surface waters may be directed either into the sewers or surface drains.

The separate system of course can only be carried out in general features not in every detail. It would be a mistake to have a duplicate set of drains to each house; back yards would generally drain into the soil sewers, but for the most part roofs can be drained into the road channels or surface drains. About 90 per cent. of the surface waters may be diverted without causing any difficulties in detail.

With regard to the polluting character of surface drainage, the author submits that the nature and amount of the pollution is not such as necessitate its diversion from any ordinary river, and it is a very small matter compared with the manurial washings of farmed lands which discharge into the rivers.

The author does not propose to discuss details, but to assert and illustrate a principle of town drainage which in his opinion must be generally adopted under the new obligations of sewage purification.

DISCUSSION.

Mr. Parry agreed with all that Mr. Angell had said in his paper, and practically knew the necessity of dividing the drainage in the manner pointed out. None other could have been pursued at Reading. The water supply to Reading was 1,200,000 gallons

per day, and the amount of sewage at the pumping station 900,000 gallons, with five-sevenths of the houses connected with the sewers. Although an attempt was made to drain every yard it was never expected to be accomplished. The pipes were carried into the back yards, and drained the rain-spouts wherever they existed.

Mr. Pritchard remarked that the question of separate systems of drainage engaged much of the attention of modern sanitary engineers. Mr. Parry had referred to one case of success, viz. Reading, where he believed they had a duplicate system of sewers. In works he had recently been constructing he found, after making every exertion in laying the sewers, that he failed to make them tight, although every care had been taken. In some cases specially prepared joints of tarred cord and cement were formed but even these broke, and he found that unless the sewer be laid in a bed of concrete and covered with the same material it was almost impossible to render a joint water-tight with an earthenware pipe. He had overcome the difficulty to a very considerable extent by an arrangement of joint which while sufficiently elastic maintains its rigidity. (Sample produced and explained.) At the present time he had considerable lengths of these pipes laid and there was not the slightest leakage. The advantage of this pipe was that it could maintain a perfect joint even where the ground in which it was laid was faulty. The separate system was one which must subsequently come into use if the Acts of the Legislature as to the pollution of streams were to be assumed as a guide. The objection to the separate system was that two sets of sewers were required. One point appeared to him to have escaped attention, viz. how to deal with the contaminated water on the surface of the streets. If this were necessary, not only would a duplicate system be required, but a triplicate system—one for sewage, one for polluted water on the roads that does not come up to the standard of purity of the Commission, and another for the rainfall on the houses. Although engineers are generally agreed upon the advisability of the separate system of sewers, there are difficulties in the way of its adoption in a large town.

Mr. Fox had derived pleasure in listening to the paper, but thought there were one or two difficulties in the way of adopting the separate system in its entirety. He would ask what would Mr. Angell do supposing he had to drain two streets adjacent to the same premises—one a front street, the other a back street? would he lay a sewer in the main street for the purpose of con-

veying away the rainfall, and two sewers in the back street, one for the sewage and the other for the rainfall? Also whether he would have a duplicate system of house drainage as well as a duplicate system of sewerage? It appeared to him that if a duplicate system of house drainage were adopted there would be a great many difficulties to contend with. For instance, if two drains were laid in back yards, one for sewage and the other for surface water, it would lead to endless confusion. In the course of a few years sewerage connections would be made with the surface water drain, and *vice versâ*. In cases where the yards sloped from the back streets to the houses, the surface water gully and the sink gully would have to be placed near each other, and servants would not be particular which they used. How would the cost of a duplicate system of sewers and house drains be apportioned in the making of a new street? would the extra cost of those for surface water be charged to property owners as well as those for sewage proper, or would such extra cost be charged to the ratepayers in the district generally? In his opinion it was better and cheaper to pump the surface water from the yards, when to separate such water circumstances rendered it necessary to lay an independent drain nearly the whole length of the yard, in addition to the ordinary sewage drain. It was cheaper, for if the area of the yard and that portion of the house roof sloping to the yard were assumed to equal 600 superficial feet, and the rainfall finding its way into the sewer at 30 inches per annum, it would follow that there would be 1500 cubic feet, or say 10,000 gallons of water to pump per annum. Now to raise this quantity 25 feet would cost 3*d*., including interest and depreciation on pumping station and machinery. However to lay the extra drain and yard gully in this case would cost the owner an extra 25*s*., and the interest on this sum would be 1*s*. 3*d*. per annum in place of 3*d*. for pumping. The author appeared to have given some attention to the duplicate system, he should therefore be glad to hear his opinions on these questions.

Mr. Isaac Shone (Mayor of Wrexham) heard the paper with pleasure, and was glad the subject was receiving the attention of the gentlemen who had so much to do with the health of the people of this country. There had been a number of difficulties in the way of adopting the separate system in its entirety. The principal reason why the mixed system was regarded as a necessity had arisen from the difficulty of dealing with sewage by itself in its passage through the pipes. All engineers were agreed that it was quite necessary sewage proper should be passed along the pipes to its destination as

speedily as possible, otherwise stagnation and decomposition was set up and noxious gases evolved. He respectfully differed from Mr. Pritchard in the observation he made as to large towns. If a means could be devised to effectually separate sewage from rain water, no great injury would arise from the rain water rendered foul by its falling over the streets. He however agreed with Mr. Pritchard that if sanitation were to be carried to perfection a triplicate system would be necessary. His pneumatic sewerage system had been on its trial at Wrexham for some months, and all engineers who had inspected it had pronounced it a practical success.

Mr. LOBLEY said there could be no question that if the rainfall could be kept out of the sewage the difficulty of dealing with the sewage would be greatly simplified. Separation resolves itself into one of degree—how far can it be carried out? He was glad Mr. Fox had drawn attention to the difficulty of sewering back yards and back passages. He thought it was pretty well agreed upon by nearly all sanitary engineers that separation was desirable to a considerable extent. He carried it out in several long streets, but in no back yards. He should be glad to hear if that has been successfully accomplished.

Mr. SMITH remarked that some gentlemen had said that there were many difficulties in the way of the separate system. He was endeavouring to carry out the separate system in the valley of the Thames, and found the difficulties very great. The district of which he spoke was unfortunately water-logged soil with water within a few feet of the surface. It was a mass of cesspools, and it was suggested to take the whole of the sewage to a main pumping station. He found great difficulty in making pipe sewers water-tight and he did not know what he should have done without Stanford's pipe. He had tested these pipes under a head of 15 feet of water, and found the pipe to all intents and purposes water-tight. A further difficulty was the amount of water taken into the sewer. All separate systems mean a sewer for the reception of sewage proper. He had found it impossible to keep the whole of the roof water out of the sewer, and in his opinion pumping was more economical than the separate system.

Mr. VAWSER said the author had contented himself with throwing out suggestions, and had supplied no facts, and no new data had been brought forward. In Maidstone the separate system might be comparatively easy, but the author had not said anything about West Ham where the population was much larger. If the duplicate system could be successfully carried out at West Ham, he was pre-

pared to give it a much more favourable consideration than hitherto. Theoretically it was perfect, but in practice it was almost impracticable in large towns. Mr. Parry had explained that the duplicate system which existed at Reading consisted in part of the old sewers, which had been retained for the surface water, and that two new systems of sewers had not been constructed. It was difficult to convince sanitary authorities that the work could be done as cheaply by the separate as by the combined system. At present he adopted one sewer for all purposes, but would be glad to modify his opinion as soon as he saw good reasons for doing so. He introduced storm overflows wherever practicable, so as to reduce the size of the sewers to a minimum.

Mr. Taylor represented a town in which the separate system was adopted and the only difficulty experienced was as to the flushing. He flushed simply from the water main.

Mr. Lemon said he had had very little difficulty in carrying out the separate system, and that it was astonishing how rapidly the system was growing. When the main drainage of London was being discussed in this room, there were diagrams on the wall showing that the separate system was absurd, and holding it up to ridicule. Now no one would take such an extreme step. As to the cost he found no difficulty in charging the owners of property with the double system. He was now carrying out two roads in Southampton, at a cost of from 2000*l.* to 3000*l.*, where a separate system of drainage was being introduced. He had not yet been able to keep the water of the back yards out of the sewers and did not consider that practicable. As regards the surface water in the city of Winchester there was not a single gully connected with the sewers which was a very important statement to make. He had never yet been able to arrive at that result, for the reason that the configuration of the ground was such that it afforded many opportunities for discharging the surface water down the valley lines. Before an engineer went to a town surface water was got rid of and if still allowed to take its natural course it would continue to be got rid of without any trouble. Sewers are found in every town and the course he adopted was to put them to the purpose for which they were originally constructed, and allow them to remain for surface water only, and put down another pipe for sewage. This reduced the cost very considerably and what is still of more importance the cost of treatment at the outfall. Brighton and other places, which have an outlet into the sea, need not trouble about the separate system.

Mr. ANGELL explained that he had been much hurried with his paper, and that he had only endeavoured to enumerate general principles; each town would have to be dealt with on its merits. There are places which discharge into the sea. He would not of course attempt to go into the separate system there. At Portsmouth he had a good outfall and drained everything into the sea. He thought the Rivers Pollution Act was never intended to keep surface water out of the rivers. The water running from agricultural land was far worse than that from the streets. Where houses were drained by down-pipe in front, he generally endeavoured to get them into the street channel. As to back and front streets, in most cases there existed a certain inclination, so that it was not necessary to carry a pipe all the way, a surface channel being sufficient to conduct the water to a gully at the bottom. Supposing the yard and roof water be allowed to go into the sewer by the separate system, nine-tenths could be cut off. At West Ham there were 5,000,000 gallons to deal with in a day, and in wet weather 15,000,000; and if of this 10,000,000 gallons could be shut out from the tanks he would consider himself fortunate. At West Ham there is a lower portion, which cannot be separated; however by carrying an intercepting sewer which is now being arranged three-fourths of the water which would otherwise get into the tanks will be arrested. As to the flushing of sewers he had a disc which could be inserted in the manholes to stop the sewer, and accumulate a sufficient head of water to carry away deposits.

Mr. MORANT thought that there was no clear definition of what sewage really was, and manufacturers generally claimed the right to send their refuse into the sewers. There was a case in which manufacturers put in two drains, one carrying muriatic acid, and the other liquid impregnated with sulphur, which caused a great nuisance. They were proceeded against, and a verdict was given in favour of the complainants.* He wished to hear if any member present knew of a case in which lime had caused stoppage in the sewers, and if the users had been proceeded against.

Mr. VAWSER replied that in Warrington they had compelled tanners to pay for cleansing the sewers, and also to prevent lime going into the sewers.

Mr. NOOT: At Tonbridge we have compelled them to do likewise, and to make pits.

* St. Helens Chemical Co., appellants *v.* The Corporation of St. Helens. Tried in the Exchequer Court, 17th Feb., 1876.

ANNUAL MEETING AT LONDON,

July 31 and August 1, 1879.

ASPHALTE, AND ITS APPLICATION TO STREET PAVING.

By E. B. ELLICE-CLARK, Assoc. M. Inst. C.E.

Preliminary.

The subject of asphalte paving has been reported upon by borough engineers, and treated in a few papers read during the last ten years, very ably so in the 43rd volume of the 'Proceedings of the Institution of Civil Engineers,' but has never, so far as the author is aware, been discussed by a scientific society in England. Its importance cannot be over-estimated by the engineers having charge of the paved streets of the great towns, therefore it appeared the most fitting opportunity of entering into the question would be when they were assembled together as they were to-day.

Few English engineers have the time or opportunity to become acquainted with and peruse the literature of the subject, spread over many volumes, in several languages; the author will therefore briefly give some particulars of asphalte before entering upon its application to street paving.

The word asphalte in England is a generic term for bitumen, and many materials and substances containing small quantities of bitumen, or mineral tar, such as the residue from the distillation of coal and heavy shale oils, and the natural bitumen from the Dead Sea (*Lacus Asphaltites*) and Trinidad; in this paper it is used only to describe the natural combination of bitumen and calcareous matter; in other words, bituminous limestone found in the Val de Travers, Neufchâtel, and at Seyssel, between Lyons and Geneva.

Geological and Chemical.

Of the geological origin of asphalte little is positively known, as it appears to have escaped the attention of eminent geologists. It has been supposed that underlying beds of coal were subjected to

fusion by great heat, and pressed through the superposed strata during volcanic convulsions, the bitumen or bituminous vapours impregnating and being condensed in the calcareous rock which composes from 85 to 95 per cent. of asphalte. This theory hardly seems tenable when it is found that seams of pure limestone, not containing any bitumen, sometimes intervene between the impregnated seams. The impregnated beds are of a finer texture or grain than the others, so that it would appear they were subject to greater pressure. The division between both is exact, though serrated or chipped, and in no instances do the seams of limestone so intervening contain bitumen. The faults are vertical, and there are no other fissures. The impregnation took place before the last volcanic upheaval of the earth's outer crust. It is thus difficult to reconcile this theory with the position of the rocks unless the beds were at a different angle to that in which they now lie, or the impregnated beds were composed of a softer kind of limestone. A curious fact is that coal has not been found in the neighbourhood of the asphalte. It has also been contended that limestone, suspended in water beneath which were springs of bitumen, has been precipitated and mixed with the bitumen, though the slight affinity that exists between the two substances does not bear out this hypothesis.

Bituminous limestone so rare in nature contains from 5 to 15 per cent. by weight of pure bitumen composed of 85 parts of carbon, 12 hydrogen, and 3 oxygen, having a specific gravity of 1·03.

The rock asphalte is pure carbonate of lime and bitumen. The seams vary from 1 foot to 23 feet in thickness; they are convex on the upper and lower sides, the beds dip to the south, and fall from 1 in 3 to 1 in 12. The disposition and mixture of the limestone and bitumen being so complete that there is no bed or flaw, as in York stone; the seams are compact and the grain homogeneous; the colour is a rich chocolate; variations of temperature affect its consistency; it is hard and easily broken, giving an irregular fracture; the specific gravity varies in direct proportion to the quantity of bitumen, the average is 2·25 (3874 lbs. each cubic yard).

Historical.

From the earliest period of the history of constructive works asphalte appears to have been used as a cement. It is claimed that the famous buildings of Babylon were jointed with it, and

Dr. d'Eyrinis, who published a work on the subject in 1721, enthusiastically advocated its use for all purposes to which cement and mortar are applied; though he, and some who subsequently worked a concession, appear to have applied it chiefly to medicinal purposes by extracting the bitumen from the earth and soft sandstone, without touching the harder limestone deposits. For more than a hundred years its employment for other purposes remained in abeyance. In 1838 a trial pavement was laid in Paris and the matter was taken up by financiers who not content with honestly giving the numerous uses to which it might be applied attributed to it qualities it never possessed, exaggerated the importance of its virtues and roundly claimed for it an adaptability to almost every conceivable object in constructive works. Speculation in asphalte became so great as to reach fever heat; panic and collapse followed, and this retarded the proper use of the material for a considerable period. It was therefore not until 1854 that the Rue Bergère was paved with the rock of the Val de Travers, compressed. It may be here stated, portions of this road were removed fifteen years afterwards, when the asphalte was found to have lost 5 per cent. in weight, and the vertical depth reduced from 2 inches to 1¾ inches. Previous to 1854 it had been laid in mastic on the Morand Bridge, Lyons.

In 1858 three sides of the Palais Royal were laid and gave results which justified its adoption in a street of 1000 yards in length. Here in consequence of unfortunate results which might have been readily foreseen the use of the material for road paving was further retarded. A large brick sewer had recently been constructed under the roadway and the made ground extended to a depth of from 10 to 13 feet. The top surface was in October prepared for the asphalte by laying down a foundation of concrete 4 inches in thickness. In November and December the compressed asphalte 2 inches in depth was laid and the traffic immediately afterwards turned into the street. Cracks and flaws on the surface and through the concrete soon appeared, but an examination of the subsoil proved the fact that the made ground was insufficiently settled; this was attended to, the cracked asphalte removed without the stoppage of the traffic, and the road has remained good to this day. Public opinion soon demonstrated the popularity of this kind of pavement and the areas so treated have increased every year. In 1867 the Paris municipality agreed to take up 24½ acres of stone-pitched pavement and replace it with asphalte. The war of 1870 stayed the completion of this great undertaking, in addition the admini-

stration became exceedingly poor and having on their hands the accumulated stock of pitchers, it is not surprising that new asphalte pavements were for a time discontinued. In December 1875, upwards of 300,000 yards super of roads were paved with asphalte, while in December 1876 this area had increased to 400,000 of roads and 1,800,000 square yards of footways.

In the municipal budget of 1875, 41,200*l.* was voted for the maintenance and restoration of these roads, and in twenty additional streets asphalte was laid, in most cases replacing stone-pitched roads, in two replacing wood, and in others macadam.

These large areas so paved in Paris naturally attracted the attention of English engineers, and in May 1869, 485 square yards were laid in Threadneedle Street, London; since that date this area has been added to yearly. In February 1879, Colonel Haywood, the City engineer, reported that "nearly every portion of the arterial lines of thoroughfare in the City was paved with wood or asphalte, and many of the secondary streets also." The figures being,

Lineal Yards.	Material.
11,299	Asphalte.
11,164	Wood.

Equal $12\frac{8}{10}$ miles.

In December 1877, the Val de Travers Company had laid 85,000 square yards in the Metropolitan roadways, while in Vienna, Berlin, and other continental cities, many thousands of yards have been put down.

In 1838, inquiries were set on foot by engineers, and analyses made, showing the composition of asphalte to be bitumen and limestone. As these substances could be obtained in abundance and at moderate cost, attempts to combine them artificially were made, and have continued from that time, in the author's opinion with little success; where toughness is required, or great pressure exercised, or heavy wear by attrition, no artificial composition of carbonate of lime and bitumen has proved equal to the natural rock.

The history of the extraction and manipulation of asphalte shows the steady development of the means whereby its production is cheapened and its application improved. Where formerly the rock was obtained in small open cuttings at the surface, it is now mined for under the guidance of skilled engineers. Manual labour has been superseded by mechanical apparatus.

In the earlier stages mastic only was used for paving, boiled on the spot at which it was laid. The incident of the road traffic of the mine grinding down under the summer heat and hardening

the mineral surface led to the application of pressure to the powder; but largely improved as are the means used in this industry, there is a wide field open to engineers in devising a mechanical method of compressing the heated powder.

Quarrying, Treatment and Manufacture.

The rock of the Val de Travers and Seyssel used to be obtained only when it cropped to the surface, but the great demand for the material has led to the seams being worked in galleries under engineering supervision; at the former place the adits are driven from the face of the mountain. The road is about 7 or 8 feet in height, and the roof and sides have to be bratticed. Most of the rock is obtained by blasting; the shot-hole is drilled with a breast auger; the charges are small. Fine dust rock is used for tamping, and the plug and firing are as for other rock-blasting operations.

Treatment of Compressed Asphalte.

The rock is brought to England, and stored in the open; it is then thrown into a steam crushing machine. This mode of breaking up the rock answers in every respect, except when it contains an abnormal amount of absorbed moisture. This occasions the crusher to clog, and it has to be frequently cleared. The material now reduced to about the size of a walnut falls on a shoot at the bottom of which passes an endless chain of buckets which carry the material up to the hopper feed of a Carr's disintegrator, which is driven, one shaft at 1000, the other at 700 revolutions a minute. It then drops to the ground and is ready for heating. This is accomplished by placing it in revolving cylinders of about 5 feet diameter, above a coal fire, the cylinders making about one revolution in two minutes. Each charge consists of about 2½ tons, and takes from two to three hours to attain the requisite temperature, which is according to the amount of vapour required to be driven off. All this work is accomplished by the judgment of the workmen. No hygrometrical test is made to ascertain the amount of moisture in the cold powder, nor is the heat in the cylinders taken by a thermometer. The state of the powder differs according to the weather, and there would be great difficulty in making any scale for determining the time or heat required for "cooking." Great care must be taken to prevent it calcining, and if it is not sufficiently heated it will not adhere enough by compression to give the surface when

laid a hard face; if overheated, the bitumen is fused, and little but limestone is left. As a rule, the mass attains a temperature of from 220° to 250° Fahr. At the latter point it may remain in bulk four or even five hours or more, and be fit to lay, the close compact nature of the powder retaining the heat for a very long time. From the heating cylinders it is taken on to the works for laying.

Application—Method of laying by Compression.

Although there are some roadways paved with mastic asphalte, it would appear this is not so suitable a material as compressed asphalte, which more than any other class of pavement requires a rigid foundation. This cannot be insisted on too strongly. Asphalte, being elastic, follows the subsidence of the foundation, even in so small an area as a few inches square. In this respect its failure of surface is different to that of a sett, which acts independently, unless it is kept up when placed as a voussoir. The substratum should be made hard and compact by ramming. If convenient, the Manchester method of laying down cinders and other hard material, and turning the traffic on it, might be adopted. The concrete should be regulated according to the weight it has to bear. The standard, of road burdens, adopted by Mr. Deacon of 100,000 tons per annum per yard of width is a convenient one, and all road calculations should be reduced to this. In the Rue St. Honoré the concrete was 5·9 inches in thickness; in the Rue des Petits Champs it was 4 inches in thickness. This road as has been already mentioned went to pieces from defective foundation, and probably the slight bulk of concrete had something to do with its failure. In Paris rarely more than 6 inches in depth is laid. Cheapside, laid in 1870 with a then traffic of 400,000 tons per annum per yard of width, had a foundation of 9 inches in thickness; after seven years' wear it was reported as being in good condition, with slight undulations of surface. Gracechurch Street with 603,000 tons per yard of width per annum had also 9 inches in thickness; while other streets, with less traffic, had 6 inches. Moorgate Street with upwards of 6000 vehicles per diem = 264,000 tons per annum per yard of width, had a foundation 6 inches in thickness; all these latter streets have maintained their surfaces in good condition This would go to prove that under the heaviest traffic 9 inches is a sufficient depth, while 6 inches is sufficient for 250,000 tons per annum per yard of width.

The concrete should be gauged, six of aggregate to one of Portland cement bearing a very high tensile strain; on no account must lime concrete be used. For the best method of making Portland cement concrete for street foundations, see p. 10, paper by G. F. Deacon, 'Excerpt Minutes of Proceedings of the Institution of Civil Engineers,' vol. lviii.; the author only wishes to add that it is hardly possible to make the concrete too dry. When the mixture is taken in the hand it should feel slightly moist; no water should exude when squeezed, but a slight sweat only; a few particles should adhere to the hand.

Whether a chemical change is set up or not by the contact of the asphalte and lime has not yet been determined; but practice has given sufficient experience to show that lime concrete ruins compressed work. A portion of Holborn was laid with a lime concrete foundation. The night before the asphalte was laid down a fire occurred in the vicinity, and the concrete was trampled over and injured, the holes were filled up with lime mortar, but the work was open only a short time when it became apparent it would not last. Time after time it was repaired, only to again break down under the traffic. The company, finding the annual cost of repairs very great, stripped the asphalte from the concrete, which appeared hard in places but generally was very soft. Twenty-four hours after the hard concrete was exposed to the air, it became granular and quite unfit for a foundation; it was removed and replaced with Portland cement concrete, and the road has remained good to this day.

And here one of the difficulties in all classes of pavement requiring artificial foundation arises. The cement to be of a high quality must be slow setting, and as asphalte must not be laid on the concrete until perfectly set—otherwise, as it forms an air-tight covering over the concrete, the latter would never obtain its maximum hardness—the concrete must be laid at least four days, with a temperature of 50° Fahr. and fine weather.

The French engineers bind the asphalte contractors to open a certain portion of the roadway in eight days. Practice in London shows that four days is not too long a time to allow the concrete to set. To expedite this work, the author suggests the trial of bituminous concrete as laid by Mr. Deacon. If, as described by this engineer, the surface of bituminous concrete "will bear in a few hours any amount of ramming without distortion," the work of laying compressed asphalte would be expedited by three days. In

all cities of great traffic, where every twenty-four hours is of importance, such a trial should be made. The concrete must be smoothed off to the exact contour of the finished surface; the transverse fall should be not more than 1 in 30.

The asphaltic powder is now brought on to the spot in open carts, and spread transversely across the street in widths of 3 to 4 feet; the powder when reaching the ground should be uniform in temperature and not less than 115° Fahr., when leaving the works at which it is heated—a maximum of 250° and a minimum of 115° Fahr. are allowed, according to the distance it has to travel; all the natural moisture is eliminated. The powder is spread out in a thickness of two-fifths more than the specified compressed section. It is raked with regularity as to thickness and width over the concrete; this operation can only be accomplished by skilled men, and must be carefully attended to, otherwise the powder, if left in unequal thicknesses, will be unequally pressed. No mechanical system of spreading the powder has hitherto been successful, a steam appliance which would accomplish this object is still a desideratum.

The powder is then rammed over all by heavy iron punners, heated in portable furnaces to a proper temperature to prevent adhesion; at first the ramming should be done very carefully, and the blows should be light so as to ensure equality of material; the force should be gradually augmented until they are delivered as heavily as possible.

Those parts abutting the stone curbs and coal-plate curbs and cills are beaten and seared over with a T tool, as the punners are of too large diameters to reach the angles. Ramming or compressing the powder may be considered the crucial, as it is the culminating point of its application.

The great difference in the muscular efforts of the workmen has always been a difficulty, and engineers have not been idle in searching for a method of compression by steam machinery. A steam hammer moving on temporary rails was tried, but the practical difficulty of laying the rails, especially for the side areas, rendered it abortive.

A steam roller was next applied; but instead of compressing and laying the powder, it was driven forward in a wave, and the cost of applying the power was great when compared with hand labour. The face of the roller was kept to a high temperature to prevent adhesion. The last method of finishing off the compression has been by having a roller of several rings, which traverses the road

transversely and longitudinally. This has not been largely applied: the most frequent method is to sear the surface with a smooth, curved iron or smoother, after the whole has been compressed with the heated punners. A straight edge, 7 or 8 feet in length, is then drawn at random over the face of the work, and inequalities of surface are shown by scratches; when these appear the face is beaten down to the required level. When the asphalte has cooled to the temperature of the atmosphere it is thrown open to the traffic.

Preparation of Bitumen and Mastic.

The powder and pieces of rock are placed in cauldrons filled with boiling water and stirred for an hour. The stirring breaks up the rock, and the bituminous portions float; the sand or calcareous stone being partially precipitated. The bituminous scum always contains about 25 per cent. of sand, to eliminate which a second process has to be gone through; though in some of the coarse-grained rocks, as those of Lussat, Auvergne, the scum is sufficiently free from the sand, and does not require a second process. The scum is again heated in water, which is converted into steam. By this second purification all the sand is eliminated; the pure bitumen floating on the surface. This is decanted into iron moulds, the weight when cold being about ½ cwt. This method of extracting the bitumen is not much in vogue, as the Trinidad bitumen is much cheaper, and serves the same purposes.

The Paris engineers specify that the stone from the Seyssel mine used for making mastic shall be naturally impregnated with bitumen of good quality coming exclusively from the mineral stone. All artificial bitumen extracted during the purification of heavy shale oils is rigorously excluded, the rock is to be soft and fine-grained, and the texture compact, regularly impregnated with bitumen so as not to show black and white spots, which would indicate that the limestone and bitumen were not thoroughly mixed together. The colour should be brown, when heated to 60° C. it must fall to pieces, and contain 7 per cent. of bitumen, 93 per cent. of limestone, and not more than 9 per cent. of free bitumen must be required to mix with it, to change it to mastic.

The different mines mould the mastic into various shapes bearing their trade marks. The hexagonal block of the Val de Travers Company is the most convenient for storage.

These blocks are broken into pieces, placed in cauldrons, and heated to a temperature of between 380° to 490° Fahr.

When the temperature is increased, the bitumen wholly evapo-

rates; if the limestone is made red hot it becomes pure. If however a small quantity of free bitumen is added the whole melts, and a complete transformation of the material is effected.

Rock containing but 5 per cent. or 15 per cent. of bitumen will not melt; if there is added from 7 to 8 per cent. by weight of free bitumen, the former will melt, though it will not be so rich in bitumen as the latter. After it has become cold it will not again melt without the addition of bitumen, so that free bitumen acts as a flux. In the preparation for laying there is added to the mastic about 60 per cent. of grit, silicated grit is the best, it must be quite free from loam or other foreign material. The quantities generally used are

Bituminous mastic	220 lbs.
Free bitumen	13 „
Grit	132 „

River ballast thoroughly dried, passed through a $\frac{3}{16}$-inch sieve, or other similar material, is used for grit.

The mastic is thrown into the boiler; when the first lot is melted a small quantity of free bitumen is added, and the mixture is stirred with an O-iron; about 5 per cent. of the total quantity is added at a time. At the third charge some gravel or grit is added; this sinks by gravity very slowly, owing to the specific gravity of the materials being nearly the same. The mixture is not moved until the grit disappears when it is stirred rapidly; the mixing continues in this way until the cauldron is full. Care must be taken when the boiling is complete the mastic is not too dry; if it is, a small quantity of free bitumen is added.

The boiling occupies from two to three hours.

The method of testing the complete boiling is by plunging a piece of wood into the mixture. If it is insufficiently boiled the mastic adheres, and *vice versâ*. It should be observed that grit is added not from motives of economy alone, but to prevent the mastic, when laid, softening by the heat of the sun. The two chief points aimed at in the preparation is to heat the mixture with as little free bitumen as possible, and to lay it as hot as practicable.

Some of the liquid asphaltes have the grit mixed when the rock is being reduced to mastic; this is so in the preparation of the Val de Travers Company, so that free bitumen alone is required to be added before laying.

Mastic is principally used for footpaths; in England it has completely failed when subjected to the heavy traffic of the London

carriage-ways, and has been replaced by compressed. If a piece of old mastic is examined, it is apparent that the cause of failure is the admixture of grit. The surface will be found covered with indentations, from which the grit has been removed. These sockets give way round the edges, and, forming so large a portion of the bulk, the whole soon becomes disintegrated. The same remarks hold good in its application to foot pavements, only the percussion from traffic being much less, it wears longer. It will be seen that the use of material other than the natural rock opens the way to adulteration; unless the engineer sees every portion of grit placed in the cauldron he can never secure a constant quantity being used; it will therefore be necessary to mention under the head of Maintenance how this evil is to be guarded against.

The laying of mastic is simple; while in a boiling state it is laid in strips about 4 feet wide on the concrete bed with wooden floats or spattels. From ½ to 1 inch is the general thickness laid. One man with the asphalte brought to him can spread 150 yards super in a day. Three tons of the material can be prepared by a workman in a day. The concrete is usually 3 inches in thickness, and laid to a fall of 1 in 24.

Durability and Cost of Compressed Roadways.

M. Chabrier states that the effect produced by wear and tear on asphalte is so trivial that it may almost be said to be imperishable so long as no other cause than friction of wheels occurs to alter its working conditions. It is hardly possible to accept such a statement without challenge, and the wear is unquestionably so slight that exaggeration is not necessary, even by partisans. The most lengthened experience in England is in the piece of road laid by the Val de Travers Company in Threadneedle Street in May 1869. In February 1877, the City engineer reported this piece of paving as having had few repairs, and being in good condition. The author examined it a few weeks ago, and with the exception of those places cut out for experiments and gas or water repairs, the surface was in good condition. It has been subjected to a traffic of 200,000 tons* per annum per yard of width. Unfortunately for

* These weights are approximate, and probably considerably under the actual weights. Each vehicle is taken to weigh 1½ ton, probably 50 per cent. might be added to them; but, as there are no means of ascertaining the weights exactly, Colonel Haywood has never given weights in his reports, so that in comparing these figures with those given by other writers the vehicles must be reduced to the standard of 1½ ton weight each, and the traffic is for twelve hours only each day.

the statement just quoted from M. Chabrier, the pavements of all cities are subject to many other incidents tending to destroy them than mere friction of wheels. The constant removal of the surface to repair gas and water mains and drainage is such that in many streets 50 per cent. of the whole surface will be removed during the life of a pavement.

Rock asphalte is compressed without appreciable wear under traffic such as the above. On the table is a specimen taken from Cheapside. It was laid in December 1870, $2\frac{1}{4}$ inches in thickness. After having been subject to a traffic of upwards of 500,000 tons per annum per yard of width, the bulk is reduced $\frac{5}{18}$, while it has lost $\frac{2}{7}$ in weight. The difference in the percentage of loss of bulk and weight is accounted for by the compression of the material. This is apparent to the depth of half an inch. Under a magnifying glass the compression can be seen to the depth of more than 1 inch. After fifteen years' wear in the Rue Bergère the loss by weight was 5 per cent. In Gracechurch Street, where the traffic is 603,000 tons per annum per yard of width, the material has lost, so far as can be ascertained, about the same during a period of eight years. These results are all obtained from the compressed rock of the Val de Travers. When other materials in mastic have been laid in streets of much less traffic, they have been replaced either with compressed or wood; and without making invidious distinctions, it may be here stated that experience in London has demonstrated the fact that no class of asphalte has stood equally well with that of the Val de Travers compressed. From 1870 to 1878 thirteen different kinds of asphalte had been tried in the City of London. At the period of writing but three remain, in streets having traffic of more than five hundred vehicles in twelve hours. The manner in which the compressed rock is laid has much to do with its duration; disintegration has taken place in many roads from circumstances that are not readily accounted for; fissures appear on the surface, so close together as to form a complete web-like appearance; the percussion of the horses' feet detach small portions of the material, and if frost supervene the road will quickly fail, owing to the crystallization of the water held between the fissures. It has been urged that this is occasioned by the execution of the work during wet weather. When the heated powder is placed on a wet surface, vapour of water is produced; this permeates the powder below the bulk influenced by compression, and it will be readily understood this prevents the perfect homogeneity of the

whole. Another cause of failure is owing to the cracks being produced by the use of too new a cement for a foundation. When the concrete fails, the asphalte will fail also. The question of durability, apart from other considerations of convenience, is the question of cost. It is therefore necessary to compare this with other materials.

The cost is reduced to 100,000 tons per annum per yard of width.

Description.	Original Cost per Square Yard.		Interest on Original Cost.	Sinking Fund at 3 per cent. Compound Interest.	Maintenance per Square Yard.		Scavenging per Square Yard.	Total.	
	s.	d.	d.	d.	s.	d.	d.	s.	d.
Wood (Liverpool) ..	15	1·5	7·5	10·1	0	1	2·7 Gravel. 5·0	2	2·3
Val de Travers compressed asphalte ..	18	0	9·7	..	0	3·6	0·4	1	1·7
Granite	17	9	9·6	0·5	0	1·3	2·5	1	1·9
Macadam	4	9	2·1	..	3	6	12·0	4	8·1

It will be observed that nothing is charged for renewal of asphalte, inasmuch as the annual sum for maintenance provides the alphalte in perpetuity. In Paris $\frac{1}{15}$ of the entire roads paved with asphalte are renewed every year at a charge of 8*d.* per square yard; but there are no precise figures whereby to reduce the cost to the above standard, as this sum includes many roads having very small traffics. In London the Val de Travers Company maintain various streets at fixed sums per annum, from which the figures in the table are arrived at. The figures for wood are those of Mr. Deacon, which the author believes are the only figures reduced to the standard that can be relied upon; all the observations of engineers in New-York, Paris, and London confirm these, although not reduced to the same data.*

From Colonel Haywood's reports it would appear that the average duration of wood pavements in the City is three years. The following will show the life of some recently laid:—

	Years.		Years.
Gracechurch Street	1½	Aldersgate Street	3
Great Tower Street	3½	Angel Street	3
King William Street	2½	Ludgate Hill	3½

* See Appendix, p. v., to Report of the Paddington Vestry, 1878; Report of Colonel Haywood on Wood and Asphalte Pavements, 1877; Report of Mr. Van Nort, of New York, December 17, 1874.

With regard to the absence of foothold for horses, the observations made in London prove that asphalte is not so slippery as granite cubes. It is now well known that when the atmosphere is humid the fine dust and dirt, ever present in a city street, are spread over the surface of the asphalte by the traffic, forming a pellicle which renders foothold difficult. In dry weather the road is also covered with the *detritus* incidental to great traffic, apart from wear. When asphalte is swept as a method of cleansing, this adheres to the surface, and becomes greasy mud with a very slight shower of rain. In Paris grit is thrown down on such occasions; but the proper method of cleansing asphalte is by hydraulic and not mechanical means. With fire hydrants on each side of the roadway this could be effected at slight cost. Hitherto this has not been done in London as there were no hydrants, but in cities where hydrants are in use the difficulty would be solved. Asphalte either wet or dry affords an excellent foothold. Trials of asphalte on a small scale are not to be relied upon. No trial can give a fair result unless a considerable area is paved. It was abandoned in Manchester, where only 968 yards super were laid; but has remained in Southampton, where 1587 yards were laid in 1873. In no case should a length of less than 440 yards be laid. Horses do not become used to the surface in short lengths, and unless the adjoining road is paved and kept clean asphalte will be not only dangerous but costly. The maximum foothold for horses will not be attained until every street in a town is paved with the same material.

Maintenance.

Hitherto in England the maintenance of asphalte paving has formed part of the original contract of construction. Engineers appear to have thrown the responsibility of repairs upon the contractors, because want of experience did not justify them in taking over the roads when once completed, and waiting results. So far as the author can ascertain, only one engineer, Mr. Lemon, reported against a fixed annual sum for maintenance. In London the prices vary from 3*d.* to 1*s.* 6*d.* per yard per annum. These prices are based upon the cost of granite maintenance, and in many cases are probably too much, while in others they are too small. The periods for which the maintenance is contracted vary from ten to seventeen years, at the end of which time the pavement is to be as good as when first laid. Whether this is an economical method of maintenance cannot yet be determined. In Paris, where the original contracts

have long expired, the work is let for seven years, and the contractors have to renew $\frac{1}{15}$ of the entire areas each year; the life of the pavement is thus fixed at fifteen years. As the application of asphalte is increased, this method will probably be found more economical than that previously alluded to, and experience will prove what areas will require renewal. To state broadly that $\frac{1}{15}$ of the asphalte must be renewed, appears a random method of determining the needful repairs. Each street should be treated on its merits; thus Cheapside would require much more frequent renewal than George Yard, and the two should be kept separate. Maintenance of road by contract has dropped into disuse in this country; but will have to be resorted to for asphalte works.

It is therefore necessary to determine when a street requires renewals. The surfaces must be replaced when there are cracks $\frac{1}{16}$ inch in width, or there are holes $\frac{3}{8}$ inch deep; or when there are depressions in a circle of 3 feet 3 inches diameter, the normal depth of the hollows being at least $1\frac{1}{4}$ inch; or when the water in the channels cannot be freely discharged, and when the joints or partings from the curbs or other paving stones are $\frac{3}{8}$ inch wide; and when the surface is blown up or lifted $\frac{3}{16}$ inch above the adjoining surface. These defects, if not repaired, will subject the contractor to a fine, according to a scale of areas and depths. With regard to the repairs to trenches, they must be paid for as new work. In the City of London, immediately the excavation is filled, the concrete is laid, and in a few hours the powder is compressed. Within the past month portions of the roadway have been opened and closed within twenty-four hours; this may be insisted on in streets of great traffic; but, for reasons previously stated, the asphalte can never obtain that firmness over such trenches as it does when the concrete is dry. In Paris a maximum period of fifteen days is allowed; while the trench is becoming consolidated, the surface is kept up with flints. Probably the most convenient mode of maintaining the asphalte would be by schedule of prices; the engineer giving directions which portions are to be relaid. The only difficulty would be:—When the contract expires under the previously described mode, the entire surfaces are to be in good condition; this compels the contractors to execute good work. The methods of preparing mastic asphalte and the different qualities are so variable, this gives such opportunities of fraud—the engineer will have to be thoroughly conversant with the details, and exercise a rigid supervision over every process, as well as sample frequently

the natural materials. For these purposes the French engineers have prepared elaborate specifications, to which reference can be made.*

Convenience—Sanitary.

One of the greatest conveniences for a crowded city is the fact that an asphalte roadway once down, so far as the road-making goes there is an end of it—the street need never be blocked a day. Cheapside has now been laid nine years; the traffic has never been interrupted one hour for making repairs to the pavement, where formerly every few years it was necessary to stop the roadway for many days. Any short-lived pavement, like wood, must offer very great advantages to compete with this advantage alone.

The advantages of paving streets with a smooth, impervious surface are so great that no one can contest the point. As to cleanliness, the results from actual observation give :—

Material.	Superficial Yards for each Load of Mud.	Traffic in Tons per Annum per Yard of Width.
Macadam	344	25,000
Granite	500	50,000
Wood	1666	25,000
Asphalte	4000	500.000

As dirt means mud in wet weather and dust in dry weather, the same proportions hold good when considering the question of dust. The asphalted streets in London are never watered; streams of water are sent down the channels where dust collects.

Absorption of Filth.

No positive statements founded on facts have ever been placed on record as to the actual amount of filth absorbed by different classes of pavement. The only fact recorded is patent to the eye, and is disputed by none, that whether other materials do or do not absorb filth and moisture, asphalte does not. Opinions only founded simply on general observation, and to be taken for what they are worth, place the materials in this position as to absorption :—

Macadam—1.	Wood—2.
Granite—3.	Asphalte—4.

* Roads and Bridges Municipal Service of Paris. Schedule and specification for footpaths and pavements in bitumen and compressed asphalte issued by the Prefect of the Seine.

Freedom from Noise.

This desideratum has led, no doubt, to the application of new materials for roads in large towns. As there are no means of measuring noise, opinions must be relied upon. When wood is new, close-laid, and the pavement is perfectly level, it may be characterized as noiseless. In consequence of the density of the asphalte the horses' hoofs can always be heard upon it; but as the surface wears away in undulations, which are not defined by such sudden vertical depressions as all pavements composed of blocks, the comparative quietude of wood and asphalte depends entirely upon the state of repair. Seeing that none of the wood pavements in London have lasted many years without being relaid in streets of great traffic (see report of their existing condition *), it appears to the author that they cannot be maintained with that evenness of surface which places them at the head of the list for noiselessness; and that on the average state of the two materials, asphalte is equal, if not superior, in this respect to any other kind of material, both it and wood being preferable to macadam, as that is to granite.

The only point now remaining is the gradients at which the material can be laid with safety. It would be unwise to lay asphalte on any gradient much steeper than 1 in 50, although a portion of Broad Street, London, is 1 in 46, and no inconvenience has been felt.

Footpaths.

Footways of mastic asphalte laid in 1838 remain good at the present time. Some of the streets in London with the heaviest traffic are laid in mastic and compressed. From observations extending over ten years, the author is of opinion that mastic asphalte is inferior to the best beds of York and Caithness stone; while compressed, reasoning from the surface wear of that laid in carriage-ways, is superior to York, and equal to Caithness. For paths of the heaviest traffic, 4 inches of concrete with 1 inch of compressed asphalte appear to be the proper quantities to put down. This may be laid for 6*s.* a yard super. Where the traffic is light, mastic may be laid at about 5*s.* a yard; but the material is so variable, and the preparation is so open to adulteration, that it would appear the natural rock compressed without the mixture of any foreign bodies, such as bitumen and grit, is the better kind

* Colonel Haywood, Report, 1877.

of material, and will require less supervision on the part of the engineer; indeed, whatever attention is given to the laying of mastic, it is impracticable to obtain the best material if those supplying it prepare it abroad, while the preparation in this country would require constant personal supervision. The author therefore advises the use of compressed rock for all classes of work, as being more durable, and consequently more economical. In laying footpaths, all gas and water service pipes should be carried through tubes. Common red-ware butt-jointed pipes, covered by the concrete, will answer every purpose, with a small mark cut in the curb to indicate their position. These laid, the path need never be disturbed, and having no joints, wearing uniformly, with a fall of not more than 1 in 24, it will compare favourably with other materials.

DISCUSSION.

Mr. Deacon (President) remarked that the thanks of the Association were due to Mr. Ellice-Clark for his very interesting paper. As to the asphalte in connection with which his name was mentioned, he thought that Mr. Ellice-Clark's suggestion to use the commoner description of bituminous concrete under rock asphalte might be advantageous. His experience of bituminous material as a foundation for sets was most satisfactory. He was afraid that Mr. Clark's paper would not have justice done to it, owing to the shortness of the time which could be devoted to its discussion; he therefore suggested that the members should communicate their views in writing, so that they might be printed with the Proceedings.

It was accordingly moved by Mr. Morant, seconded by Mr. Parry, and carried unanimously, "That the members communicate their views in writing."

ANNUAL MEETING AT LONDON,

July 31 and August 1, 1879.

ROCK-CONCRETE TUBES: THEIR MANUFACTURE AND USE.

By C. FLETCHER WOODS.

In writing a paper upon this subject the author trusts he will succeed in placing at the disposal of the members of this Association some information regarding the mode of production and the characteristic properties of concrete in the form of sewer pipes, principally acquired since being engaged by Messrs. Henry Sharp, Jones and Co. to superintend their Bourne Valley Works.

The process of manufacturing a slight hollow tube of great strength and without a flaw requires constant care and attention. Faulty cement, dirty sand, soft aggregate, and careless manipulation are dangers to be guarded against, or a considerable amount of material may be spoilt.

Sewer pipes of concrete have been used in the United States for the last thirty years. American engineers report that they were laid in New Bedford as early as 1845, and are still found in perfect condition when met with in the course of laying water mains. The cementing material used in the United States however has not hitherto been the best that could be procured. A native production, termed Rosendale cement, has been used with a small admixture only of English Portland. This has necessitated the pipes being made of abnormal thickness; for instance, 9-inch pipes of 1-inch scantling and 18-inch pipes of 2 inches scantling. The moulds first used at Bourne Valley were procured from America, and were *fac-similes* of the foregoing. An unwieldy article of this description would not have succeeded in England in competition with the vitreous stoneware pipes of Poole and Lambeth, by reason of the weight and consequent cost of freight and handling.

In this country Mr. William Buckwell, an engineer, may be considered the scientific pioneer of the manufacture of pipes. As

early as 1849 he patented a process which consisted in "condensing, solidifying, and compressing such matters by subjecting them to percussion in moulds." This system of solidifying by percussion has not been improved upon to the present day, but his mode of putting it into practice by means of steam hammers, and his process generally, appears to have been too slow and complicated for it to become of practical value; and though he carried out several successful examples of his work which still remain, it was not sufficiently appreciated and no more has been heard of it.

To Messrs. Sharp, Jones and Co. belongs the credit of having first made the manufacture of Portland cement concrete pipes a practical and commercial success in England. That firm took up the question of making pipes of concrete, which was introduced to them by Mr. J. W. Butler, now of the East Greenwich works, and it started the American machinery which he had brought from the States. Troubles and difficulties were sufficiently overcome for the process to be shown in successful operation to the late Mr. James Hodges, a man of experience in the use of concrete. The establishment of another manufactory at East Greenwich followed his visit to Bourne Valley. Such has been the introduction of concrete pipes into this country. The great strength of concrete in the form of sewer pipes, which is so much above what concrete has generally been supposed capable of attaining, is primarily the result of solidifying by percussion, combined with a small and regular feed of material under the rammer.

The exceptional feature in the manufacture of rock-concrete tubes is the nature of the aggregate, viz. broken vitreous stoneware or the waste of stoneware pipe works. Mr. John Grant has pointed out that concrete made of broken pottery is much stronger than that made of gravel, and Table A, showing experiments made by the author for the purposes of this paper, is confirmatory. It will be seen that the average shows an advantage of 25 per cent. in favour of the stoneware aggregate, and it will be noticed that the lowest breaking strain of the stoneware was better than the highest of the gravel mixture. These test blocks were made in the usual course, the gravel being clean, and part of a few tons got in water-bearing strata in the neighbourhood, and of similar description to Thames ballast.

The combined manufactures of stoneware pipes and rock-concrete tubes afford an excellent example of the utilization of waste products. The stoneware is passed through a Blake stone-breaker,

and then under edge runners. The fine is at each stage intercepted and returned to the pottery to be again worked up in the manufacture of stoneware, while the coarse now reduced to the size of pea gravel goes on to the rock-concrete department. It is here mixed by machines with the washed sand and a fine heavy Portland cement specially ground from picked clinker. Thence into the automatic feed of the tube-making machine. Large tubes require a heavy and regular blow and also a regular feed which cannot be attained by hand, however carefully performed. The tube is built up on the coil principle, and the mould being filled the spigot is formed by means of a heavy iron ring mould subjected to heavy blows.

Great care is necessary throughout the above process. The exact proportion of water is of much importance. It is easier to make and compact the tubes when an excess of water or sand is used, but the point aimed at is to make good tubes with the least possible quantity of either. All moisture beyond that sufficient to set up the crystallization of the cement detracts from its strength, and if in great excess is liable to weaken it by washing out the soluble silicates. The sand partakes more of the nature of an economical distributor of the particles of cement than of an aggregate, though to some extent it is an aggregate as it helps to fill up the interstitial spaces that would otherwise exist.

The tubes when finished are placed on trucks and run out to the hardening ground, where they remain twenty-four hours in the moulds, of which they are gradually divested, the outer casing being the last to be removed. After standing on end for a week or ten days, during which time they are constantly watered if the weather is dry, they are removed to silicating tanks, from which a week later they go into stack, there to complete induration. A few words may be said as to the process of silicating and its results. Messrs. Sharp, Jones and Co. make their own silicate bath under Highton's patent. The *modus operandi* being to dissolve at a temperature of 500° the natural silica found in the neighbourhood of Farnham by means of caustic soda. The silicate of soda thus formed is reduced to the required dilution by the addition of hot water, 1130 specific gravity by the hydrometer being the strength most suitable for the purpose. The silicate thus produced can be relied on as absolutely pure and of good quality. The tubes constantly absorbing the silica, the tanks have often to be replenished so that the silica in solution may be taken as constant. A steam boiler serves to make the solution, and to supply power to

pump the liquid from one tank to another as required. As to the utility of the process there is no doubt that it hastens very much the natural induration of Portland cement, but it does not penetrate far into the material, and the stronger it is the less it penetrates, the result being a temporary case-hardening—temporary, because it does not appear that any property is conveyed to the cement that would not eventually accrue by age. It benefits the manufacturers by enabling them to place their goods sooner in the market.

A detail of much importance and to which great attention is paid is the regular and continuous testing of the cement by tensile strain. Tests are first made in the usual way of each consignment of cement as it comes on the works, including the tensile test at seven days. Testing briquettes are also made daily of both the cement and of the tube mixtures in which it is incorporated. All these are entered in the test book, which records particulars of each parcel of cement, where it came from, and what becomes of it. Thus should any defect occur in the manufacture the cause can at once be traced to its source. These numerous briquettes are all kept, and tested from time to time as occasion requires. An instance of their use quite unanticipated when the briquettes were made is Table A. The author contemplated compiling an elaborate series of tables from the records of these tensile tests, but on consideration he did not think himself justified in publishing such as the results of scientific investigation, when as a matter of fact the testing is merely a guide, though a very valuable one, to those engaged in the manufacture, and many seeming discrepancies would arise which though at once to be accounted for on the spot would be difficult and tedious to explain in a paper. The author may however state as a general deduction that at the end of four months the concrete is not more than 10 per cent. below the strength of neat cement, and that this difference continues with a tendency to diminish as the age of both increases. This favourable result must be to a great extent due to the inherent strength of the stoneware aggregate and the capital "bite" that it affords to the matrix. It should be mentioned that the test briquettes are not silicated, the object being to arrive at the value of the concrete on its own merits.

A record is kept of another kind of testing that must have a higher practical value to engineers. This consists of submitting tubes to a crushing strain under a hydraulic ram, the breaking weight being read off the dial of a self-registering gauge. This

machine is by no means in daily requisition, since the breaking of large tubes is costly, and not to be undertaken without a specific object. Still seventy-six experiments have been made in this way, some of which the author has recapitulated in Tables B, C, and D. The most noteworthy are the comparative experiments made by Messrs. Welman and Creeke for purposes of investigation connected with the Bournemouth drainage. The stoneware pipes averaged 256 lbs. in weight, and the rock-concrete tubes 252 lbs.

A feature prominently demonstrated by the experiments is the great toughness of rock-concrete tubes.

The density and impermeability of the material is demonstrated by Table E of experiments made by Mr. Henry Reid, showing absorption of moisture after *ten days'* immersion to average 1·7 per cent. addition by weight. The average absorption after twenty-four hours' immersion by stoneware and fireclay, as shown by a number of experiments given by Mr. Baldwin Latham, is 3·057 per cent.

Having described the general features of the manufacture a few words may be said on the uses to which the tubes may be applied. They are applicable to the construction of main sewers, and without claiming for them the quality of marvellous strength, it may safely be said that *cæteris paribus* all experiments show them to be somewhat superior in this respect to stoneware pipes.

As regards durability the concrete being chemically and mechanically as perfect as the finest selected cement and aggregates and modern machinery can make it, this quality necessarily follows. Sir John Coode, Mr. E. Druce and others have testified to the extraordinary powers of resistance to the action of attrition or abrasion possessed by concrete; and as regards resistance to the chemical action of deleterious liquids, it would be mere waste of time to enter into argument in defence of its well-known qualities in this respect. Although at Bournemouth a sewer constructed of rock-concrete tubes was found to have cracked longitudinally, in consequence of ordinary engineering precautions having been neglected, it does not come within the author's experience to have heard of a concrete sewer that has succumbed to fair wear and tear. Brick sewers have been thus worn out or eaten away and the author, as a town surveyor, has had occasion to pull up many hundred feet of fireclay pipe sewers, which although only laid for periods varying from six to seventeen years were absolutely rotten. He was obliged to relay with others of a similar material, through

motives of first cost, and which cannot last but a very few years. At Frome, in Somersetshire, fireclay pipes have been discovered in a like condition. It is not surprising that this should be so for fireclay as its name implies withstands the action of the heat, does not vitrify, and pipes made from it have only the salt glaze to protect them from the destructive effects of water, to say nothing of the more deleterious liquid that they are specially intended to convey. Stoneware on the other hand as made in Lambeth and Poole is the product of clays that partially vitrify under the action of intense heat, and as Mr. Reid has shown in experiments made upon the aggregate of rock-concrete tubes for the Bournemouth Commissioners, may be subject to boiling hydrochloric acid without deterioration.

With the above-mentioned qualities of strength and durability, rock-concrete tubes become a desirable material for the construction of large sewers. In the ordinary sizes of pipe sewers they can be used as stoneware pipes are used, and for the larger sized sewers they are simply invaluable as permanent cores and linings to an exterior casing or ring of coarse concrete. This mode of construction costs less than sound brickwork. In addition the perfectly concentric form, and imperviousness, the saving of centering, and the possible rapidity of construction and filling in the trenches immediately after, show them to possess great advantages over other modes of making such sewers. As a rule the sizes vary from 15 inches to 36 inches diameter. The process of manufacture not being adapted to the economical production of small tubes, here stoneware pipes cannot be competed with.

The joint has been objected to as too short to allow of settlement, and the same objection has been raised to the Stanford patent joint. Doubtless such objection holds good if a rigid sewer is to be laid on a shifting bed, but when the tubes are enveloped in concrete or laid thereon, as any pipe or brick sewer should be if the ground is bad, this objection is no longer a valid one. The jointing is easily and perfectly effected with Portland cement, the material being specially adapted to it. In the 15-inch, 18-inch, 21-inch, and 24-inch diameters, provision is made to effect a good joint round the outside. With larger tubes there is room to make the joint inside as well as outside.

In view of using the tubes in watery ground, the author has been making experiments with a mixture of boiled tar, pitch, and plaster, whereby the water is excluded for a sufficient time for a

cement joint to be made and to set *inside* the tubes, and he has attained a fair measure of success.

Mr. Ellice-Clark's experience in the use and behaviour of the rock concrete has been considerable and he in addition to constructing sewers with the tubes has used them for man-holes and ventilating shafts. Mr. Cregeen of Bromley and Mr. Stow of Frome may also be mentioned among others as having used the tubes with success and satisfaction. Two or three wells have been constructed with them of 30-inch and 36-inch diameters, one being 44 feet in depth. At Bourne Valley they are used for water tanks, and also for a hydraulic balance lift, the cylinders being 12 feet in depth by 18 inches diameter.

The author hopes that these few facts which he has been able to compile relating to a new industry may be found of interest to the Municipal Engineers and Surveyors of this country.

Table A.

Showing Difference in Tensile Strength between Concrete made with Washed Gravel and with Broken Stoneware, age 5 weeks.

	Lbs. per Sq. Inch.		Lbs. per Sq. Inch.
1 part of cement	170	1 part of cement	220
1 „ washed sand	169	1 „ washed sand ..	192
2 parts of pea gravel ..	146	2 parts of vitreous stoneware	220
Mean	161·6	Mean	210·6

Table B.

	Breaking Weight, in Lbs.		Breaking Weight, in Lbs.
18-inch stoneware pipes ..	5104	18-inch rock-concrete tubes	5880
	3663		5104
	2552		4536
Mean	3773	Mean	5170
15-inch stoneware pipes ..	940	15-inch rock-concrete tubes	3528
	2556		3360
	3528		4468
Mean	2340	Mean	3785

TABLE C.

Tests made by Messrs. Creeke and Welman, October 1878.

	Breaking Weight, in Lbs.		Breaking Weight, in Lbs.
24-inch stoneware, 1⅝ inch thick, 2 feet long and average	2352 2553 2301 2940 2258	24-inch rock-concrete tubes taken from the Knyveton Road sewer, Bournemouth drainage, 1⅝ inch thick, average weight 250 lbs. ..	2520 3360 3192 3024 3360
Mean	2481	Mean	3091

TABLE D.

A 24-inch rock-concrete tube, 2 inches thick, and weighing 330 lbs., broke under 4700 lbs.

A 30-inch rock-concrete tube, 2¼ inches thick, and weighing 403 lbs., broke under 3360 lbs.

A 36-inch rock-concrete tube, 2⅝ inches thick, and weighing 500 lbs., broke under 2772 lbs.

NOTE.—*These pipes, as well as those of Tables B and C, received no lateral support whatever, and the strain was imposed direct by hydraulic pressure.*

In the following cases the tubes received lateral support as described:—

A 24-inch rock-concrete tube, 1⅝ inch thick, supported laterally, cracked under 4788 lbs., but, though further fractured, no collapse was attained with a weight of 10,080 lbs., when a tap gave out and ended the experiment.

A 30-inch rock-concrete tube, 2¼ inches thick, and weighing 402 lbs., well blocked up to and above the springing, cracked under 5040 lbs.; pressure increased, with further cracking and distortion, but without collapse, to 16,800 lbs.

Experiments at Hove, by Mr. E. B. Ellice-Clark.

	Breaking Weight, in Lbs.
24-inch rock-concrete tubes, 250 lbs. weight, 1⅝ inch thickness, 2 feet long, bedded in clay up to and above the springing ..	4938 4121 4121
Mean	4393

TABLE E.

Experiments by Mr. Henry Reid, showing Amount of Water absorbed by Cubes of Rock Concrete during a Period of Ten Days.

	Weighed Dry.	Weighed Saturated.	Increase in Weight.
	grammes.	grammes.	per cent.
No. 1	300	304	1·33
„ 2	279·5	282	·9
„ 3	*269·3	277	2·86
		Mean	1·7

* Cut from a tube purposely selected as probably defective.

The discussion of this paper was taken along with that on the following paper by Mr. J. W. Butler.

ANNUAL MEETING AT LONDON,

July 31 and August 1, 1879.

THE MANUFACTURE AND APPLICATION OF SILICATED STONE FOR SEWER TUBES.

By J. W. BUTLER.

Many will no doubt remember the opposition to the introduction of the glazed earthenware pipes, many and fierce were the battles fought, but slowly and surely they made their way, owing to their greater fitness for many positions than the ill-constructed barrel drains of the period. In sound pipes there are, at all events, only two joints, one at either end; but in "barrel drains," unless constructed with radiated bricks and laid most carefully in cement, there is a drain full of joints. The manufacture of cement pipes was commenced at East Greenwich in the premises lately held by the Ransom's Artificial Stone Company, which are admirably situated for the purpose on the River Thames. The *modus operandi* may thus be briefly described. The material to be crushed, whether Kentish ragstone, slag, granite, or Thames gravel, is taken to a Blake's crusher and reduced to the required size; it is then passed through a washing machine, where every particle of dust is eliminated, then to a mixer, and from this to the machines for pipe making or other purposes. Before leaving this part of the subject the washing of all material, *however* apparently clean, cannot be too much insisted upon, for it has been found from numerous experiments that the washing makes a difference in the tensile strain of the briquette samples of from 15 to 25 per cent. This is beyond dispute. The character of the machinery employed is as follows:—

The mixing machine consists of a circular iron trough, with part of the bottom cut away, and replaced by a plate put underneath, and so arranged that it can be moved either to close the opening or expose it, handles being attached to the plate for this purpose. A vertical shaft passes up through the centre of this

trough and carries a bevel wheel at its upper end driven by means of a bevel pinion mounted on a pulley shaft. Upon the vertical spindle, and close to the bottom of the trough, two mixing arms or paddles are placed. These in revolving thoroughly mingle the cement and ballast, which are moistened by means of a rose nozzle. The amount of water added is variable and determined by experience; it must be sufficient to permit of the mixture, when prepared, retaining a true surface when smoothed over with the trowel. The concrete is then taken to the moulding machines, of which two different arrangements are employed, the first for smaller pipes up to 12 inches diameter, the second for those to 2 feet or 36 inches diameter. The former machine consists of a wooden frame, carrying at a convenient height the moulding table. A large circular opening is made in the middle of this table, and the space is occupied by a slightly coned hopper, the centre of which is cut away so as to leave a circle corresponding to the size of the pipe being moulded. The moulds are placed in pairs upon a board running on the rollers before mentioned as constituting the tramway, and one of these moulds is brought under the machine, immediately beneath the mouth of the hopper. A cylinder of such a diameter as to enter freely the annular space between the inner and outer side of the mould is mounted on a vertical spindle, placed in the centre of the machine, and driven by bevel gear. A key-way is cut down the whole length of this spindle, and a feather in the top of the cylinder enters it, and is thus rotated, although it is left free to rise and fall. At the bottom of the cylinders are four projections of the thickness of the pipe to be moulded. These projections each extend a considerable distance around the cylinder, but do not touch, so that between each a space is left to allow the concrete to fall into the mould, and to facilitate this the projecting pieces are bevelled off on the under side at one end. The top of the cylinder is formed with a projecting rim, and over it is placed a loose bar, through which the vertical shaft passes. A lug at each end of the bar on its under side is placed so as to catch the projection around the top of the cylinder, which can thus be raised at pleasure. When the mould is in place, and the cylinder at the bottom of the annular space, some concrete is fed in from the hopper at the top, and the machine is set in motion. The spaces between the projections around the bottom of the cylinder allow the concrete to fall, and the rapid motion of the cylinder combined with its weight serves to compress the concrete in the mould.

Gradually, as the material is fed in and becomes compressed, the mould is filled, and the cylinder is raised, until the pipe is made. At the commencement of the operation it is necessary to raise the cylinder by means of the cross-bar before mentioned, about a foot, and permit it to fall upon the concrete in the mould in order to compress it and secure moulding. As soon as one operation is completed the hopper is lifted, and the board carrying the moulds pushed forward till the second one comes into place, and the work is recommenced. The second moulding machine consists of a wooden framework like the former, but the moulding table has a hole in the centre the size of the pipe to be made, and over the inner part of the mould a cover is made to prevent the concrete from falling through. The stamper consists of a vertical bar with an enlarged head of a thickness corresponding to that of the pipe. Reciprocating and revolving motions are given to the stamper, by means of suitable gearing, which allow blows ranging from 50 lbs. to 500 lbs. being given to the concrete in the moulds. As the concrete is fed in and the moulds become filled the stamper bar is lifted, and so is always free during one part of each stroke. The moulds consist of a cast-iron ring to make the base, and of such a shape as to form an ogee socket at the end of the pipe. The outside of the mould is formed of sheet iron bent into a circle, and secured by three latches on the outside, and the inside of the mould is also of sheet iron with two latches on the inside. When it is desired to form T pipes or elbows, a circular hole is cut in the outside of the mould, and this is covered with a plate also secured with latches. When a mould is filled, the other part of the socket remains to be formed. This is done by adding a little more cement in the top, and placing over a cast-iron ring, the inside of which is formed to the contour of the socket. By hammering the mould upon the concrete and turning it round by hand, the male portion of the joint is made, and it is finally trimmed off with a trowel. After the pipes have remained sufficiently long in the moulds, they are taken out and placed in a bath of silicate of soda to hasten their induration. Mr. Baldwin Latham having suggested that the material should be subjected to certain tests, Mr. Henry Reid was employed to test the pipes,* with the following result.

No. 1 briquette fourteen days old, and kept in water, having a breaking section 2·1 inches, broke at 496 lbs., being equal to

* The samples were made of the ordinary material used in the manufacture.

236 lbs. per square inch. No. 2 briquette seven days old, and kept in water, having a breaking section of 2·06 inches, broke at 464 lbs., being equal to 224 lbs. per square inch.

The samples of material were carefully analyzed, and the chemical value of the gravel compound found to be as follows:—

Water and loss	5·15
Oxide of iron and alumina	3·47
Lime	15·23
Soluble silica	10·80
Silica in the shape of pebbles and quartz	62·20
Magnesia, alkalies, carbonic acid	3·15
	100·00

Mr. Ellice-Clark, in making a series of tests, found the cracking weight of a 24-inch tube, submitted by the author, to be 7245 lbs. The form of joint is an ogee. In laying the pipes they are luted with a thin slip of Portland cement of about the consistency of cream, and the pipes themselves being formed largely of the same material as the cement forming the joint the whole drain becomes practically monolithic. Among the advantages claimed for silicated stone pipes may be mentioned their greater strength when compared with glazed stoneware pipes, the ability to make a more perfect joint, the ease with which the works can be inspected before the ground is filled in, and their non-liability to split longitudinally when placed in positions where great traffic occurs.

Mr. Baldwin Latham, in his work on 'Sanitary Engineering,' points out "that a concrete pipe is capable of withstanding the jars arising from heavy traffic over the streets even better than an earthenware pipe, which is a quality of no small advantage, he having found that in some districts earthenware pipes have been found to split in a singular fashion, the cause of failure being due to the constant tremor of heavy traffic in the streets." It is curious that small percussive taps may injure a glazed earthenware pipe, causing it to what is technically called fret, this being a starry fracture of the salt glazing. When thus injured, many pipes are unable to withstand the damaging action of sewage matter and sewage gases. The silicated stone pipes are not nearly as brittle as stoneware, and a blow which would shiver completely an ordinary earthenware pipe would simply drive a hole, *without starring*, through a silicated stone pipe. This it will be readily understood is an immense advantage, as from this peculiarity connections may be the more readily made when additional junctions are required.

Tests have been made to try the joints. Two pipes were cemented

together for some time (about fourteen days) and then submitted to a tensile strain, and their separation has not been effected even with a depended weight of a ton and a quarter. Another experiment consisted in having a length of 12 feet of pipes cemented together and supported on bearings 11 feet apart. Upon the middle of this weights of nearly a ton were placed, and fracture took place about 6 inches from the third joint, which was not in the slightest degree injured. Their fitness to sustain the pressure of a head of water has been fully proved by an erection of pipes 30 feet in height filled with water, the slightest indication of leakage or percolation not showing either at the joints or in the body of the pipes.

Silicated stone pipes are much benefited by contact with sewage and the gases generated by it. This is borne out by Mr. W. Macklay, in a paper read by him before the American Society of Engineers, where he says that he had twenty-five tests made of Portland cement mixed with fresh water and immersed in sewer water, which averaged a tensile strength per square inch of 306 lbs. Of a similar number of tests made with fresh water and immersed in fresh water, the average strength was only 265 lbs., thus showing that concrete is positively benefited by being immersed in sewage. This is caused by the soapy substances containing silica in the sewage uniting with the Portland cement and assisting to harden it. During the construction of important sewers to which was connected the waste flow from certain chemical works, the author found that the gases generated acted on the brickwork so as to completely destroy the structure of the bricks, but leaving the Portland cement joints uninjured, and forming a sort of honeycomb, thus proving that Portland cement pipes are infinitely superior to brick sewers in their lasting properties.

Too much stress cannot be laid on the importance of testing the cement used for specialities, or indeed for any structural purpose. Owing to the comparatively thin wall of the pipes, it is a necessity that the cement should be of the very best quality—heavy, slow-setting cement—finely ground to a fifty linear gauge if possible, and with not more than 10 per cent. residuum. The cement should not be used earlier than two or three months after grinding, nor before the cement has been spread out in a waterproof building on a dry floor, and protected from the rays of the sun. Cement which has been subjected to the sun's influence for a length of time has been found to have deteriorated in a very remarkable manner. Neither should cement that has once "set" or

"gone off" be used for any special purpose. The use of such cement has been the cause of much annoyance, and has given rise to much correspondence with the cement merchant or manufacturer, who is not to blame otherwise than for having sent cement direct from the stones for the use of the customer. As long as users will buy cement from the manufacturers without guarantee as to age, they will be subject to many of the risks of using a bad cement. Although age will not make a bad cement good, it will rectify some of the dangers of an over-limed cement. That cement should be made of one uniform quality cannot be too much insisted upon, but, whilst the raw materials of which cement is made are put into the wash-mill in such a delightfully primitive style—trusting to Bill, Jack, or Harry's eye to gauge the quantity filled into each barrow—what can be expected but that cement will differ in quality? Every care should be taken that the mud and chalk are as nearly as can be in one uniform condition, and then each should be carefully weighed in the proper proportions. Cement manufacturers will perhaps contend that this would add to the cost; but it would be so infinitesimal, and the gain in quality would be so great, that the result would be largely to their advantage, and their brand could be relied upon. At present, scarcely any English manufacturer's cement is uniformly good, for the reason just detailed. On two occasions the author has been shown over the works of the great Boulogne cement manufacturers, Lonquéty and Co., and was much struck with the exactness with which every detail was performed, contrasting very favourably with the modes here. For the materials of which cement is made, no country is so favourably situate as England, and it only remains for the manufacturers to use the care taken in several of the large foreign works to get cement of the same high quality and take the lead. The cement made by the Stettin firm, Toepffer, Grawitz, and Co., is of very high quality, and they guarantee the cement, after a seven days' test, to stand 1280 lbs. breaking strain on 2¼ square inches. The cement supplied by this firm to that of the author has been of a very excellent quality.

DISCUSSION.

Mr. Reid remarked that he was sorry to find in Mr. Butler's paper an evidence of want of accurate knowledge of the true properties of good Portland cement. The author stated that cement should be kept from two to three months before it was fit to be used

for concrete purposes. It would be impossible for manufacturers to keep a sufficient stock to allow of this being carried out in practice; and even were it possible, it would only be encouraging a false system, directly opposed to the proper manufacture of Portland cement. He had advised the author to use the cement of Messrs. Toepffer, Grawitz, and Co., who voluntarily undertook to guarantee the cement, and who did not keep an ounce of stock to overcome their blemishes of manufacture. When the cement left the grinding and sifting machinery it possessed the desired qualities, and was as accurately mixed as the ingredients in any other chemical process. He said there was a difficulty in arriving at the relative values of cement owing to the variety of testing machines which were employed. He thought the President had done as much as any engineer to reduce the matter of testing to a standard. The German operations of testing were very different to those in vogue in England, and their manufacturers produced cement of great strength. He had a briquette of German cement which had broken at 1630 lbs. on the square inch of section, not on the section of 2·25 square inches, and he thought English manufacturers ought to be able to produce similar results.

Mr. Deacon (President) said that his experience was that cement certainly improved by being kept a few weeks.

Mr. Butler thought that the uncombined free lime became neutralized by atmospheric action. He was happy to find that the competition of Germany in English markets had had the effect of improving the quality. His firm had bought the German cement on the express understanding that it had been manufactured for more than six months.

Mr. Ellice-Clark wished to make a few remarks on the concrete tubes themselves, as he was under the impression that he was the first to use concrete tubes in England for sewer purposes. Two years and a half ago he laid an 18-inch concrete pipe sewer in an 18-feet cutting in stiff clay, which was almost waterlogged, and he recently went down the manholes and found the material perfect in every respect. The pipes had sustained the weight, and being always in the water the cement had indurated more quickly than in the open air. He had effected a saving of 33 per cent. in the cost of work at Hove by the use of these pipes, and he had used them 24 inches in diameter in cuttings 15 to 18 feet deep. In all cases concrete was put over them. At Brighton concrete could be obtained from 7*s.* 6*d.* to 9*s.* per cubic yard. So far he had had no failures, and

believed the more the subject of concrete tubes was inquired into and investigated the more they would be used.

Mr. Morant thought that the weight of 2400 lbs. given in Table C for a 24-inch pipe was a very small result. In consequence of finding some 30-inch pipes broken with longitudinal cracks at the top he had a short time back made the following experiments at Leeds. A trench was cut in clay ground to the exact shape of the lower half of the pipes, and they were covered with earth to the depth of 1 foot. The pipes were loaded with pig-iron as follows over a length of 3 feet.

Pipes 30 in. diameter ..	Thickness, $2\frac{1}{8}$ in.	Weight applied,	10 tons	3 cwt.
„ 30 in. by 21 in. ..	„ $1\frac{3}{4}$ in.	„	10 „	3 „
„ 24 in. diameter ..	„ $1\frac{1}{2}$ in.	„	8 „	2 „

With these weights there was no sign of injury in any of the pipes.

A 30-inch drain-pipe was also tested at the Corporation yard, Leeds, in gravelly and sandy ground, the bottom not being so exactly cut to the shape of the pipe as in the first experiments. The pipe cracked longitudinally under a weight of 7 tons of pig-iron over a length of 3 feet.

Further trials were made at the Corporation yard where a trench was dug in gravelly and sandy ground without cutting the bottom of the trench to the shape of the pipe, but straight down, leaving the sides to be filled in with earth. The pipes were all loaded with pig-iron until fracture occurred, which in all cases was longitudinally. The length of bearing on the pipe was 2 feet 3 inches. The weights were as follows:—

Pipes 24 in. by 18 in. ..	Thickness, $1\frac{1}{2}$ in.	Weight applied,	5 tons	19 cwt.
„ 18 in. diameter ..	„ $1\frac{1}{4}$ and $\frac{1}{16}$ in.	„	5 „	7 „
„ 20 in. by 15 in. ..	„ $1\frac{3}{8}$ in.	„	6 „	11 „
„ 15 in. diameter ..	„ $1\frac{1}{8}$ in.	„	4 „	2 „
„ 16 in. by 12 in. ..	„ $1\frac{1}{16}$ in.	„	2 „	15 „
„ 12 in. diameter ..	„ 1 in.	„	3 „	16 „

The chief cause of failure seemed to be the insufficient support of the sides of the pipe when the ground is excavated wider than the pipe, and the sides filled in loosely or with inadequate ramming of the earth. The space being narrow it is difficult to ensure the earth being rammed sufficiently solid round the pipe.

Mr. Lobley had not had any experience with concrete pipes; however, in his district (Staffordshire) broken pottery formed the principal aggregate for ordinary concrete. Mr. Wood in his paper had alluded to the aggregates being broken vitreous stone-

ware. This was no doubt good if properly broken up, but it should not be glazed. He agreed that it was undesirable to retain the fine sand. The strength of the German cement said to have broken under a weight of 1630 lbs. would depend on the length of time it was made.

Mr. Reid remarked that the sample he referred to was made up and broken on the 28th day.

Mr. Lobley further said that he had had English cement which had stood a test of 1000 lbs. on the square inch at 28 days, the same cement having broken at 460 lbs. on the square inch at seven days.

Mr. Cole had found several pipes in a shallow cutting broken along the top in a manner similar to those experimented upon by Mr. Morant, whereas when the earth pressure was great the pipes were sound. This convinced him that fracture was caused from the upward pressure of air in the inside of the pipes; he therefore had ventilating shafts introduced, and found the pipes answered remarkably well.

The President said that what Mr. Reid had remarked in respect to cement purging had given him much pleasure. If English manufacturers could supply cement that would not require purging, time and trouble would be saved owing to its not having to be stored. At Liverpool the cement was stored in a small warehouse. It was first hoisted to the upper chamber, where it was laid out on the floor; it was then let through a trap-door to the next room, where it was spread out and turned over from time to time and then carted to wherever it was wanted. The increase thus caused in the actual strength of the cement was often 100 per cent. He admitted it would be better if this were not necessary, but he thought it must be admitted that cement could not be obtained in England straight from the kiln which would not require purging. His experience was that great fineness increased the strength of the cement when used for concrete. When used for mortar in proportions not greater than one to three there was no appreciable increase, as the particles of the coarser cement were sufficiently numerous relatively to the particles of sand to envelop them.

Mr. Parry did not consider that concrete pipes would readily take the place of others now in use. However, he thought Portland cement concrete slabs might replace York paving in the South of England, as they cost but two-thirds the price, and looked

remarkably well when down. As regards wear, he had seen the artificial slabs outwear the York flags.

Mr. Sharp regretted that Mr. Woods, the author of the paper on rock-concrete tubes, was not present. He might say in reply to Mr. Reid's insinuation (if such it could be called) that good Portland cement could not be obtained in England, that the firm to which he belonged used very large quantities of this material, and that they experienced no difficulty in obtaining all that they required weighing at least 116 lb. to the bushel, but he could not say that it would reach 140 lb. to the bushel.

Mr. Butler regretted that his views did not coincide with those of Mr. Reid on the question of using the cement direct from the manufacturers. He was satisfied that English cement ought to be stored, but he was pleased to hear that Germany could supply cement that could be used at once, as in the event of a press of work it could be sent for to that country.

Mr. Isaac Shone endorsed the remarks of Mr. Ellice-Clark with respect to the use of silicated pipes, and he thought that there was a great future for them. He had carried out experiments at Wrexham with these pipes, which were of a satisfactory nature, but he was sorry not to be in a position to lay the results before the meeting.

Mr. Jones proposed a vote of thanks to the authors of the papers, which was carried unanimously.

The President then adjourned the meeting, and the members of the Association visited the works of Messrs. Doulton and Co., Lambeth.

ANNUAL MEETING AT LONDON,

July 31 and August 1, 1879.

THE DEVELOPMENT OF THE MANUFACTURE OF STONEWARE FOR SANITARY AND ART PURPOSES.

By HENRY DOULTON.

The members assembled at the pipe factory in the High Street, Lambeth; after inspecting which they proceeded to the new buildings upon the Albert Embankment, where Mr. Henry Doulton delivered an address on "The Development of the Manufacture of Stoneware for Sanitary and Art Purposes."

Lambeth had he said been long noted for its potteries, and he believed it was quite an ancient seat of pottery manufacture. Speaking of Lambeth he also included Vauxhall which was in the parish of Lambeth. About the middle of the 17th century workmen from Holland settled in Lambeth and gave an impetus to the manufacture of delf ware, but salt-glazed stoneware had for many years been the chief product. Stoneware was a dense, hard, sonorous substance. It was not absolutely necessary that stoneware should be salt-glazed if it had all the qualities of denseness and sonorousness, and was made of clay which would stand a high degree of heat and would also resist acids.

Lambeth stoneware was made of clay found in Devonshire and Dorsetshire. Persons were surprised that in Lambeth it was possible to produce articles at the prices at which they were charged; but when he told them that clay was brought from Devon and Dorset by sea at the rate of about 5*s*. 6*d*. per ton, they would understand that they were able to make use of the finest clays procurable.

He would explain to them the difference between salt-glazed stoneware and all other kinds of pottery except the very commonest

ware, and some kinds of bricks. Most kinds of ware were fired at least twice—first in the "biscuit" state, and secondly in a saggar or box, and were thus protected from dust and from the destructive gases evolved from the coal. In the biscuit state the ware could be handled with ease, and it could be painted and decorated in any desired style. It was then dipped in glaze of about the consistency of cream, after which it was again put into the kiln (still in saggar), when, the heat melting the glaze, the pattern shone through and became visible as shown in the specimen exhibited. There could be three, four, or more firings; as for example, when the decorations were in gold, or where there were delicate tints and colours to bring out; often a separate firing being required for each.

Salt-glazed stoneware had but *one* firing, and that not in a saggar, but in an open kiln, and exposed to the direct action of the flame. In Lambeth until within the last forty years the use of salt-glazed stoneware was chiefly confined to common articles such as ginger beer and ink bottles; but as the material was very pure and strong, it was found to be admirably adapted for the production of vessels used in the manufacture of chemicals, and capable of withstanding the action of acids.

"Doulton ware" was introduced about ten years ago, and the beautiful specimens exhibited were all burned in an open kiln, with the flames playing around them, and sometimes a charming harmony of colour was thus produced. He need not inform them that to procure these colours had been a work of considerable difficulty and the result of numerous experiments; for instance at the first attempt to obtain blue, the colour had turned out black.

Mr. Doulton then described the process of salt-glazing. At the highest temperature of the kiln, the salt (chloride of sodium) thrown in was converted into vapour, and decomposed by the silica of the ware, forming silicate of sodium which produces the surface glaze. This process takes place at the close of the firing and usually lasts from ten to fifteen minutes.

Salt-glazed stoneware was produced extensively in Staffordshire many years ago—about 1730 or 1750 it was very perfect. His friend, Professor Church, had amongst his collection of pottery some admirable specimens of these early productions; but, unfortunately, some 1600 of such specimens were destroyed in the Alexandra Palace fire. There were few of such pieces now to be obtained.

The manufacture of salt-glazed ware in Staffordshire had died out. The difficulty of getting good shapes in this hard ware, the risk of firing in the open kiln, and the British demand for articles more uniform in appearance led to the gradual discontinuance of the manufacture. Now there was not a single salt-glaze kiln in Staffordshire. Lambeth, Bristol, and Fulham were the centres of this industry up to a recent period, when it was discontinued at Bristol. At the last-named place about forty years ago what is called the "enamelled" stoneware was first made, and in consequence it is often termed "Bristol ware." They would observe in the specimens of this ware a uniform appearance. This like the salt-glazed ware was treated in one firing. But the article is dipped into a glaze formed of felspar and flint and the top coloured by manganese. In this ware druggists' pots, spirit bottles, and numbers of other articles were made. Lambeth was however chiefly and essentially a salt-glazed pottery district.

He would now call attention to the marvellous development in salt-glazed stoneware pottery during the past thirty-five years, and the causes of such progress. For about sixty years the manufacture of pottery in Lambeth had gone on with considerable increase. In 1820 there were only sixteen small kilns, producing ware to the value of about 300*l.* weekly.

In 1846 he met Messrs. John Roe and John Phillips, and discussed the practicability of supplying stoneware pipes for house and street drainage at a moderate cost. He was deeply indebted to Mr. Roe and Mr. Phillips for their advice, and he was encouraged to proceed with such improvements that they were able to advocate the use of these pipes for sanitary purposes.

He himself had made pipes on the wheel, and he had paid workmen as much for making them as the pipe itself now realized at some works. Since then sanitary science and the use of stoneware had advanced *pari passu*.

Though the demand has arisen for more artistic and attractive-looking pottery for indoor use, salt-glazed stoneware for strength and durability combined with cheapness is now and is likely to remain unrivalled for sanitary purposes.

His firm had been first in the manufacture of stoneware pipes, and had introduced improvements of all kinds in sanitary appliances.

His father, Mr. John Doulton, commenced in Lambeth as a

potter sixty-four years ago, and he could recollect the time when a barge of clay and a barge of coals were considered to be a very good stock (a "freight" * of clay being distributed amongst several potters), and when one blind horse sufficed to turn the mill to prepare the requisite quantity of clay, and the excitement that prevailed when the first steam engine of 8 horse-power was erected. The works of his firm at Lambeth without including the new buildings upon the Albert Embankment now covered seven acres.

At Rowley Regis they have two large factories, and two large ones at St. Helens; also one at Smethwick. One of these is no doubt the largest pipe works in the world.

In 1878 the number of persons employed in their various works was 1600, and the quantity of clay and raw material prepared during the year was 125,000 tons. Steam power employed (not including a large 100 horse-power engine lately supplied to the new building,) was equal to about 800 horse-power. In the same period 48,500 tons of coal were consumed.

The average quantity of drain pipes they produced was 25 miles per week, or 1300 miles per year; in sizes from 2 inches to 30 inches diameter. He would now specially notice the history of the *Doulton ware.*

At the 1867 Exhibition in Paris some rather good shapes of vases, &c., were shown which readily sold and which he would now be willing to buy back at several times the price they realized. In 1871 was held the Ceramic Exhibition at South Kensington, where the specimens were at first put under shelves almost out of sight. But their merits being observed some were transferred to cases and properly exhibited. He was encouraged to proceed and since then this ware has found a place in every museum in Europe, in many in America, and even in Japan.

He would presently show them the process of "throwing," or as as it was called in Lambeth, "turning." It was an art which he himself had practised and it seemed to him one of the most interesting of all arts.

Moulding was death to art. He would be ashamed to see a piece of Doulton ware with a seam upon it, indicative of its having been "moulded." A few years ago throwing was gradually going out of use. In Staffordshire it was almost entirely discontinued for

* Small shipload, 150 to 300 tons.

beautiful shapes. It was so easy when a shape was produced to pour a little plaster of Paris upon it and reproduce it in any quantity by moulding. But that was not art. Those fine Greek vases so familiar in exhibitions were made upon the potter's wheel in precisely the same way as the vases, &c., which were now before them. The artists engaged had to execute the original design for each piece of Doulton ware. All was "handwork"; and as a rule designed by the same person who actually did the work. Take one of the pieces before them. It had been formed upon the wheel. The pattern had been scratched or incised upon it. Colours that would stand the trying test to which he had alluded were put upon it, all the while in its clay state. Then it was placed in the kiln and the fire playing about it the colours were brought out by salt-glazing. They now had the blue and indeed the whole range of colours as exhibited. He was speaking to sanitary engineers, and he thought that this ware ought to be used even more extensively than it was in sanitary work. They were introducing it for cups and handles in waterclosets, knobs, bosses, &c., both for indoor and outdoor use as well as for plaques and tiles. It was not only suitable for domestic and indoor uses, but would be found perfectly durable under the most trying circumstances. Even strong acid trickling down upon the pieces would not harm them or destroy the colours. He had no doubt that in the future this ware would be largely used for architectural and sanitary purposes.

Then there was the "Lambeth faience" for tiles, panels, plaques, &c. There was a bath-room adjoining, fitted with panels, tiles, &c., which they would presently have an opportunity of inspecting. He did not claim the credit for the invention of this ware, as was the case with Doulton ware. But very much had been done in introducing good shapes, and adapting it (the faience ware) to practical purposes.

The speaker here pointed out that ornamental pottery was admirably adapted for decorating apartments for sanitary uses.

Of the new "Doulton Impasto ware" he had not time to speak at length.

The first specimens of this ware were drawn from the kiln upon the morning of the recent visit of the Princess of Wales and the Crown Princess of Germany to the pottery.

The ware was made upon the wheel and the patterns laid upon it in high relief. It was then fired and when in the biscuit state

was coloured and again fired. It was thus as strong as ordinary pottery, but of course not so durable as Doulton ware.

Mr. Doulton then quoted at some length from a speech made by Mr. John Sparkes, and concluded by expressing a hope that the visit of the Members might prove to be an interesting one.

DISCUSSION.

Mr. Lemon said he had had the pleasure of knowing the late Mr. Doulton, and he thought that both father and son were entitled to the thanks of the art world for their efforts and successes in the production of art pottery.

Mr. Doulton, in reply to a question as to whether all the artists employed were English, said that not only were they so, but that they all belonged to Lambeth. There happened to be in Lambeth one of the best schools of art in England, and he had received assistance for many years from Mr. Sparkes, the head master, who had placed the resources of the school at his disposal. Some of the artists who had been students of the school had shown great talent. There was George Tinworth, whom he might call a genius, and who had lately executed a large panel for the reredos of York Cathedral, and was now designing panels in the same class of work to be placed all round the Guards' Chapel in Wellington Barracks, St. James's Park. Miss Hannah Barlow likewise had remarkable talent. She drew the animals upon the beautiful vases and jugs which were around the room; and there were very many other artists he would wish to mention did time permit.

Mr. Deacon (President) proposed a vote of thanks to Mr. Doulton.

Mr. Lobley, in seconding the proposed vote of thanks, said he considered it perfectly wonderful that the beautiful pieces of ware which were exhibited had been exposed to the direct action of the flames. He had lived for a number of years in the principal pottery town of Staffordshire, and although Mr. Doulton was quite justified in calling attention to the small amount of "throwing" there practised, most potters still retained one or more throwers.

The vote of thanks was carried unanimously, and the members of the Association then proceeded to visit the show-rooms, art studio, library of sanitary works, and general factory.

DISTRICT MEETING AT MERTON,

December 5, 1879.

ADDRESS OF THE PRESIDENT,

EDWARD PRITCHARD, C.E., F.G.S.

Gentlemen,—It has been the custom for the President of this Association to deliver to the Members at the General Meeting at which he is elected, an Inaugural Address. In consequence, however, of circumstances with which you are familiar, this Address was omitted on the occasion of our last Annual Meeting held in Westminster, the election of President not having then taken place.

Since that time, the final ballot of the Members on the election has been taken, and as a result, I find myself placed in the honourable position of President of this important body, for which distinction, I beg to tender to you, Gentlemen, attending this district meeting on behalf of the general body, my most sincere thanks.

I confess it was with feelings of considerable diffidence that I accepted this reponsibility, following, as I do, those gentlemen all of whom have so successfully, and with such great ability, discharged the functions of President. Your interests shall, however, have my best possible consideration, and I will use every endeavour to faithfully perform the duties of the important trust which you have thought fit to commit to my care, with advantage to this Association, and with satisfaction to myself.

We are assembled to-day at Merton for the purpose of hearing papers read, and, through the kindness of Mr. Baldwin Latham, C.E., we shall have an opportunity of inspecting the important works now in the course of construction for the Croydon Rural Sanitary Authority. As the time for reading the papers and for

the inspection of the works is somewhat limited, I will at once proceed with the few remarks which I have briefly prepared for this occasion.

"All work connected with Sanitary Engineering should tend to increase of comfort, improvement of health, and lengthening of life; and as in this world there is no value but in and through human life, there are no duties of greater importance than those belonging to, and devolving upon, the Associated Municipal and Sanitary Engineers and Surveyors of Great Britain. Every Member should realize this, and strive in his work to leave the district, village, town, or city, better than he found it; that there should be money's worth, as the result of the labour and capital expended. Each Sanitary Engineer is, in his works, writing history, which will be more enduring than the loftiest and proudest architecture.

"The seat of civilization may change. The strength and glory of England may depart; but the sewers and drains now being buried in the earth will remain to attest her wisdom in having provided for the comfort and well-being of her teeming population in the day of her greatest riches and power; the site of her great cities, as now in the East, being indicated solely by ruins."

The above extract, Gentlemen, is the concluding portion of a letter addressed to the District Committee of the Association of Municipal and Sanitary Engineers and Surveyors, by the Chief Engineering Inspector of the Local Government Board, Mr. R. Rawlinson, C.B., C.E., on the occasion of a meeting held in Wolverhampton, in the early part of last year, and I venture to hope that the broad views therein expressed of a sanitary engineer's duties, and the determination to remedy existing sanitary evils, are endorsed by each individual Member of this Association.

It is now nearly nine years since the first meeting in connection with our Society was held in the offices of our respected Past-President, Mr. Angell, who is, very properly, looked upon as the founder of this Association, which, having for its object the advancement of sanitary science, is justly entitled to the status which, by the exertion of its members, it has secured for itself in the country.

Since its formation, Meetings of the Association have been held in London, Warwick, Birmingham, Manchester, Leamington, Liverpool, Leicester, Chester, West Ham, Barrow-in-Furness, Tottenham, Coventry, Northampton, Reading, Cheltenham, Oxford,

Bristol, Kidderminster, Portsmouth, Sheffield, Dartford, Bradford, Wolverhampton, Southport, Exeter, Wrexham, and Derby.

At these Meetings papers have been read, many of them possessing considerable merit, and these, in a collective form, are published annually, forming a useful compendium of varied experience. I need scarcely add, that the system adopted of visiting different towns and inspecting the various works therein, combined with the papers read on those occasions, has aroused a feeling of considerable interest, and has been the means of diffusing useful information. The facilities thus offered for comparing notes and the interchange of knowledge, with the inspection of different engineering methods, has had the satisfactory effect, in many instances, of eradicating deep-rooted prejudices; thereby not only promoting the professional interests of the Members, but also the general advancement of sanitary science.

Judging from the energy displayed by the various Members of this Association severally engaged in the construction of important works connected with Water Supply, Sewerage, Paving, Tramways, and similar undertakings, I have no doubt Mr. Rawlinson's admonition to improve with each advancing step is kept steadily in view by each Member, and I hope that his prediction as to the permanency of our works will be fully realized.

But this Association is not the only body desirous of improving the sanitary condition of society. The Sanitary Institute of Great Britain also takes up the principle, and judging from a few extracts from a circular issued by them, and which I shall read to you, it desires not only to assist society in its attempts to provide health-preserving appliances, but it also further wishes to improve the professional standing of the Local Surveyors themselves; and to add weight to their action in this direction, the Institute proposes "to obtain as early as possible on behalf of the Institute a Charter of Incorporation," and in its solicitude for the welfare of the Municipal Engineer and Surveyor, proposes to determine by examination his fitness for the office he desires to occupy.

The objects of this Institute are set forth in the following extracts:—

> "To examine and grant certificates of competency to Local Surveyors and Inspectors of Nuisances. The examinations shall be held at such times and in such places as the Council may direct.
>
> "A Board of Examiners shall be appointed by the Council;

such Board shall consist of gentlemen representing Sanitary Science, Chemistry, Engineering, Architecture, and Sanitary Jurisprudence.

"The examination for Local Surveyors shall include a competent knowledge of the Statutes relating to Sanitary Science and Construction, and of Engineering."

The subject of proposed examination naturally suggests two points for consideration:—

1st. Is such an examination as proposed for the office of Local Surveyor necessary or sufficient?

2nd. If an examination be necessary, is the Sanitary Institute of Great Britain the proper authority to conduct such an examination and grant the Certificate of Competency?

As the Institution of Civil Engineers and the Royal Institute of British Architects—two thoroughly representative institutions, incorporated by Royal Charter—do not submit their members to examination, the first point may be considered as most decidedly a debatable one.

And on the second point, it would seem that the propriety of the Sanitary Institute—though numbering in its ranks some eminent names—conducting such a proposed examination, must of necessity be considerably weakened by the fact of its being entirely a self-elected body, which has yet to furnish proof of its fitness for the position it would assume.

It is, however, satisfactory to know that this subject is at the present time receiving the careful consideration of our Council, in consequence of the action taken by my predecessor, Mr. G. F. Deacon, during his year of office, and in which he was strongly supported by Messrs. Angell and Ellice-Clark, to whom the best thanks of the Association are due for the interest so promptly shown.

I desire also to direct your attention to the subject of Government protection, a question frequently discussed, and one which has received both the strong support of some, and the condemnation of other gentlemen who have occupied the presidential chair.

The Acts of the Legislature of 1847 and 1848, which gave official existence to the Sanitary Engineer and Surveyor, also gave protection to the Local Surveyor who performed his duties in an impartial and legitimate manner.

It is certainly very difficult to understand why subsequent

legislation has reversed, in this respect, the position of the Surveyor, and has transferred the kind of protection once enjoyed by him to the Medical Officer of Health and the Inspector of Nuisances.

The duties of the Town Surveyor very frequently are of so onerous and peculiar a description, that any attempt to enforce the carrying out of sanitary regulations in a perfectly impartial manner would simply render him obnoxious to many persons interested, and in some instances would even render him liable to dismissal, his only error being that "he served not wisely but too well."

The necessity of Governmental protection has been ably put before the Association by our first President, Mr. Angell, in his Inaugural Address, delivered 2nd May, 1873; and the evidence which he submitted conclusively points to the fact that, for the Local Surveyor in small districts, nothing short of that protection which is afforded the less important officer, the Inspector of Nuisances, will avail. How such a consummation is to be attained, appears to be a problem difficult of solution.

I trust, however, this subject may again receive the careful consideration of our Council, and that some means may be devised by which a Clause similar to that contained in the Public Health Act of 1848 may be inserted in a Supplemental Act, which may be passed at an early date.

Notwithstanding the great depression of trade which has unfortunately prevailed throughout the country during the past year, engineering works of great importance have been carried out in connection with Water Supply and Sewerage of towns and rural districts, and schemes of considerable magnitude are also projected.

The construction of Tramways has also occupied a considerable portion of the attention of the Municipal Engineer and Surveyor, nearly every town of any importance having either a Tramway in operation or one in course of construction.

The duties of the Municipal Engineer and Surveyor are so numerous, and the demands upon his knowledge so varied and important, that I cannot conclude without remarking the great utility of an Association like this as an agency for good, bringing as it does under the notice of its Members engineering works, important sometimes from their magnitude, sometimes from the vital questions to be decided and the evils to be remedied by their operation.

Every source of information is valuable; and to the Municipal Engineer, dealing as he must in the course of his professional practice with projects calculated to promote the health and well-being of his fellow-subjects, and the absolute destruction or mitigation of those disease-producing agencies found in bad water, foul gases, defective ventilation, and other enemies of human life, an Association like this, which submits for his immediate consideration the various methods of dealing with these destructive elements, must be especially valuable, not only to himself as a professional man, but also to the Sanitary Authority which employs his services in the promotion of the health, and consequent happiness, of the inhabitants of the district under its care; and I trust and believe that every member will endeavour to realize Mr. Rawlinson's idea to its fullest extent, and thus leave the particular locality with which he is associated better than he found it.

DISCUSSION.

Mr. Charles Jones (Hon. Sec.) said that he thought the President's Address was itself open to discussion, as it seemed to him to touch upon points of very considerable importance and interest to surveyors. For instance he had raised questions with respect to Government Protection, also with respect to the Sanitary Institute and their proposed Charter and proposed Examination of Surveyors.

Mr. Pritchard (President) remarked that it would give him the greatest possible pleasure if the subjects indicated by Mr. Jones were discussed and ventilated by the members.

Mr. Jones then remarked that the subject of the action of the Sanitary Institute and its bearing upon local surveyors was one of very great importance. It was one in which not only every member of this Association but every local surveyor throughout England was deeply interested. There were a variety of opinions as to the necessity for examinations, but he and others who had been engaged in connection with this Association from its beginning could turn over correspondence in relation to this matter which would surprise the members. One thing was very certain, and that was that he and many of the members of the Council had a very decided objection to the action taken by the Sanitary Institute. Not because he and other surveyors objected to examinations, but because the question arose as to whether the Institute

was the proper source from which the examination should spring. He would say of the Institute, "God help it and speed it in its work!" believing as he did that it comprised amongst its Council men who were perfectly in earnest in all their doings. As at present constituted the Institute was a strangely heterogeneous body, and not an Association whose certificate a local surveyor would feel at all elevated in possessing. If an examination was to be held in connection with the appointment of surveyors, let it be undertaken by that Institution to which they all looked up—the Institution of Civil Engineers. Should that Institution establish an examination which should be either absolute or otherwise, its certificate would be something for a man to go into the world with, for it would emanate from a Society which engineers knew to be well capable in every way of giving a certificate which would be a mark of honour to those who held it. The Sanitary Institute was an Association formed of all classes, young and old, and even comprising ladies. He did not know whether they proposed to have lady examiners, but there were several lady members. He should protest against an examination held by the Sanitary Institute under charter, but it was at liberty to do as it pleased as an unchartered body.

Mr. CRAGGS said he was willing to submit to any examination, either by the Institution of Civil Engineers or by their own Association, but he should not care to be examined by medical officers. He thought that as an Association their object was to oppose such an examination and to prevent the Sanitary Institute of Great Britain obtaining a charter to hold an examination for local surveyors and to grant certificates.

Mr. LEWIS ANGELL stated that he had ventilated his ideas on this subject in the Council, and Mr. Jones had given full expression to the opinion of the Council. He was not opposed to examinations. Personally he thought that it was desirable that all holding the office which sanitary engineers held should have passed a proper examination, but examinations could not be applied to civil engineers and architects and artists in the same way as to the medical profession. There was however certain general knowledge which ought to be in the possession of every one who held office as a municipal engineer or surveyor, and this knowledge an examination might test. But he protested most energetically against a new body which had only just come into existence, and consisting of "all sorts and conditions of men" and women, setting themselves up to appeal to Government for a charter to examine the municipal

engineers of this country. He asked if the medical or any other profession would submit to such a thing? If an examination was established, it ought to be conducted by some corporation which had the confidence, not only of the public, but of the profession. A body like the University of London would be the proper one to be entrusted with powers to examine. At all events as engineers they protested, and would use all their influence against authority to conduct examinations being conferred upon a new body such as the Sanitary Institute. He remarked that Captain Douglas Galton was present, and that that gentleman had at the Croydon Congress very recently vindicated the scheme which was now under discussion, and that on the same occasion Dr. Carpenter, according to the report in the *Times*, went so far as to say he hoped that no Local Board would appoint any one who did not possess the certificate of the Sanitary Institute. At present the certificate of the Sanitary Institute was not worth the elaborate ornamentation which had been expended upon it. The questions in the calendar were most absurd and ridiculous to submit to an engineer, and such as the merest tyro ought to be able to answer, and would not prove anything whatever with regard to the qualifications of the candidate. Of course the Sanitary Institute aimed at a higher examination, but notwithstanding that he thought that it was not the proper body to be entrusted with the powers which they sought.

Captain DOUGLAS GALTON said that as a member of the Sanitary Institute and as having acted as one of the examiners he would remark in reference to the observations of Mr. Angell, that although the questions which were put were remarkably simple, yet of those who came forward for examination only a very limited number either of inspectors of nuisances or of surveyors were able to answer them. He believed it to be of the highest importance to the well-being of the community that the town surveyors who were appointed should be shown to possess a sound sanitary knowledge. Just as no person was allowed to practise medicine without having shown to a qualified body of examiners that he possessed knowledge of his profession, so it was desirable that every town surveyor should show before his appointment that he had a thorough knowledge of sanitary science. He did not at all say that the Sanitary Institute was the best body for conducting the examination. It had however the merit of having come forward and endeavoured to show that an examination was a want which ought to be supplied. His own feeling was that it would be better that the educa-

tional bodies of the country, such as the Universities of Oxford, and Cambridge, and London, should give a diploma in hygienic science rather than that it should be done by a new body like the Sanitary Institute. He would observe that the Institute did not admit ladies as its fellows, and it had taken some considerable pains in the election of fellows, and to ensure that the fellows were persons possessing qualifications which would raise the character of the Institute. At the same time, he agreed that it would be better, for the purpose of dispelling feelings of jealousy, that either this Institute, or the Institute of Civil Engineers, or the educational bodies of the country, should grant diplomas for sanitary knowledge other than a new body like the Sanitary Institute. He held it to be of the greatest importance for ensuring the efficient carrying out of sanitary works that a surveyor before his appointment should be required to show that he possessed adequate knowledge of sanitary science and practice.

The President, in concluding the discussion on this subject, said he thought that they all agreed that the object in view was an important one although they might differ slightly as to the method of obtaining it. All the speakers except Captain Galton seemed to have thoroughly agreed with the views which he (the President) had expressed in his opening address. Captain Galton was very deservedly held to be an authority on all sanitary matters, and he was a gentleman whom they were certainly proud to receive amongst them that day. The opinions which he had expressed in defence of the Sanitary Institute might be considered as very strong ones. In the first place he had told them that very few candidates could answer the simple questions to which Mr. Angell had alluded, but as to the cause of failure, it would have assisted the meeting very much if they could have known the names of those who had presented themselves for examination. He thought that they would agree with him that the failure must be due to the fact that the better class of men purposely declined to be examined. He believed that that was the solution of the problem. They were not informed whether the persons who had failed were members of this Association or not. It would have been very interesting to have information on that point. Captain Galton had also stated that it was necessary for medical men to receive a certain diploma before practising: but it must be observed that the two great Institutions of Architecture and Engineering, although they were truly representative Institutions and included amongst them the very best men in

the country, did not submit their members to examination. He saw a great difference between an examination of medical men by thoroughly qualified medical examiners, and the examination of local surveyors by gentlemen who were not practically acquainted with the work of the local surveyor. He believed that every member of the Association was anxious that there should be an examination; but they also desired that the examination should be conducted by persons who were properly qualified for the purpose.

DISTRICT MEETING AT MERTON,

December 5, 1879.

JUNCTION BLOCKS, AND THEIR ADVANTAGES IN PIPE SEWERS.

By JAMES CRAGGS.

In the course of the professional experience of the author, he has observed that stoppages in drains are in a great measure due to refuse, such as sticks and rags, which finds its way into the sewers and collects about the imperfect joints. A large portion of this refuse is admitted by the manholes and ventilators, and the object of this paper is to bring before the notice of this Association a junction block which has been designed by the author with a view of making a more perfect joint than is usually made with ordinary pipes built into the manhole as at present, with a less amount of labour. These blocks are of two classes, one being formed with a socket for the reception of the pipe, and the other with a neck of the size of the pipe to which they are to be connected.

The blocks are likewise fitted with stoppers or valves, which can be opened or shut by means of an iron rod passing up the manhole or ventilator, so that the sewage can be shut off from the sewers when it is desired to effect repairs; and also if all the valves be shut the manhole may be charged with water, either from a gauge van or from the water mains, and so any or all of the sewers may be flushed without difficulty.

The author would point out that these blocks are only suitable for small towns, and that so far the valves do not work perfectly watertight; but the leakage is small and he hopes to be able at no very distant date to get over this difficulty and render them perfectly tight. A large number of these blocks have been used in the sewerage system of Shildon and East Thickley which has been designed by the author. The cost is not great, as will be seen by the following prices, which include hard wood stopper and delivery on the site of the works at Old Shildon:—6-inch block, 2*s.* 6*d.*;

9-inch, 3*s*. 9*d.*; 12-inch, 6*s*. 3*d.*; 15-inch, 7*s*. 9*d.*; 18-inch, 9*s*. 6*d.* each.

Iron stoppers may be adopted in some instances but the author considers those constructed in wood to be preferable, as they are not so heavy and consequently may be moved from place to place with greater facility.

In building the blocks into the manholes it has always been the practice of the author to place the outlet block 2 or 3 inches above the bottom of the manhole, which his experience leads him to construct with flat bottoms in place of the usual invert. Any refuse will then be deposited in the bottom of the manhole and so can be removed at pleasure.

The Weardale Coal and Iron Company have manufactured blocks of the description now under consideration at their works at Tudhoe, Spennymoor, in the county of Durham, from 6 to 18 inches, and that firm is prepared to supply them up to 30 inches, free from kiln cracks and all other defects and salt-glazed inside and out.

The author in conclusion will only ask his *confrères* to give their opinions freely as to the value of the blocks which he has now the pleasure of bringing before them.

A sample junction block forwarded by the author not having arrived, it was held to be impracticable to discuss the paper.

DISTRICT MEETING AT MERTON,

December 5, 1879.

THE SEWERAGE WORKS FOR THE CROYDON RURAL SANITARY AUTHORITY.

By W. SANTO CRIMP, Assoc. M. Inst. C.E., F.G.S.

The sewerage works at the present time under course of construction for the Croydon Rural Sanitary Authority involve the construction of over 36 miles of brick, brick and concrete, and pipe sewers; the erection of a pumping station with the necessary machinery for pumping the low level sewage and for the subsequent treatment of the sludge; the preparation of an intermittent filtration area for the purification of the sewage; the construction of an iron bridge over the river Wandle; the boring of an artesian well, and the erection of two detached cottages; in connection with the sewerage and disposal of the sewage of the parishes of Beddington, Merton, Mitcham, and Morden, and the hamlet of Wallington, Surrey, containing a rapidly increasing population estimated at the present time at about 17,000 and an area of 10,101 acres.

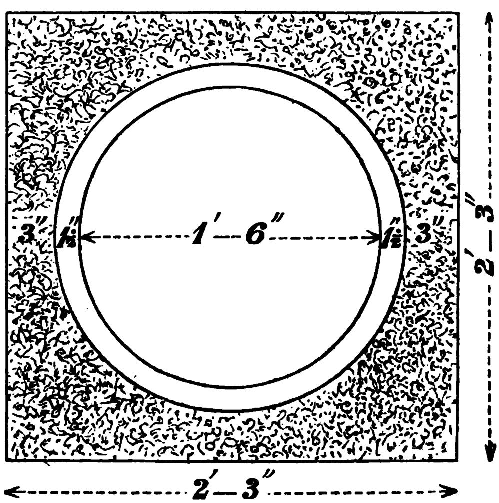
The system adopted throughout for the drainage of these districts is the water-carriage system with which all engineers are familiar. The rainfall is not admitted into the new sewers, but is conveyed directly to the natural watercourses, by the sewers and other channels existing previous to the construction of the new system, which are in every case retained for this purpose.

Nearly the whole of the sewage will flow directly on to the filtration area by gravitation alone, a portion only of the districts of Merton and Morden, containing at the present time about 300 houses, requiring the services of a low level outfall, from whence the sewage is subsequently pumped at the sewage works from a depth of 20 feet into the gravitation outfall.

The sewers are of four types. No. 1 is the stoneware, salt-glazed, socket drain pipe as manufactured by Doulton and Co. The mode of

jointing these sewers is as follows :—Tarred gasket is first forced into the joint, which has the effect of preserving the concentricity of the pipes, and of preventing the entry of any sand into the sewers; the annular space is then filled with neat Portland cement and a fillet of the same is worked around the outside. Care is taken that no cement shall form a projection on the inside of the sewer, each joint being carefully cleaned as the work proceeds. In very wet ground the water in the trench is pumped down from a sumph in advance of the sewer, until the cement joints are made, when a layer of puddled clay is placed around the newly made joint, which serves the double purpose of keeping the cement in place until set and of stopping any possible leak that may occur through the accidental fracture of a joint on the subsequent refilling of the trench. The pipes previous to being laid in the trenches are fitted together on the surface in convenient lengths, so that the invert may be perfectly true, and the space between the socket and spigot such that a sufficient quantity of cement may be admitted all round to ensure a watertight joint. All pipes having more than

FIG. 1.



a slight deviation from the true circular form are rejected, it being impossible to meet the above requirements with ill-shaped pipes. The pipes are each tested by being struck with a small hammer by means of which the presence of a flaw is readily detected.

No. 2 is a combination of the stoneware pipes as before described, with Portland cement concrete, in the manner illustrated by Fig. 1. This method of construction is adopted for sewers up to 18 inches in diameter when laid in deep cuttings in treacherous ground.

No. 3 section of sewer is represented by Fig. 2, and is the type which has been adopted for the main gravitation outfall. This sewer is constructed of an inner ring of brickwork, surrounded with a Portland cement collar joint 1 inch in thickness, the whole being embedded in Portland cement concrete. The collar joint has been introduced for the purpose of keeping the sewer watertight, and has been found most efficient. The method of constructing these

Fig. 2.

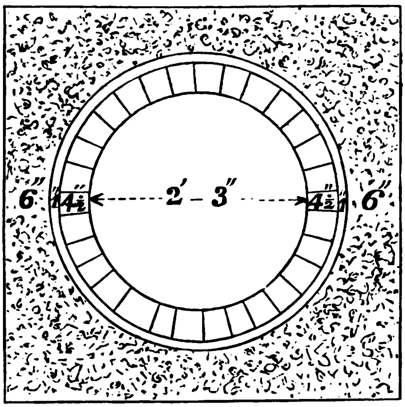
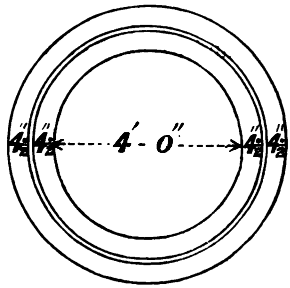


Fig. 3.



sewers is as follows:—6 inches of concrete having been placed on the bottom of the trench, a semicircular mould like an inverted centre is placed thereon; the concrete is then well worked in up to the springing, and the moulds are not removed until the concrete is thoroughly set; on the removal of the moulds the collar joint and brickwork are proceeded with, and the remainder of the concrete in due course.

No. 4 section of sewer, of which Fig. 3 is an illustration, has been adopted for the tank sewer, for the reception of the low level sewage during the time the pumping engines are at rest. It is constructed of two rings of brickwork with cement collar joint as before described between the inner and outer ring. The importance of constructing the whole of the sewers as nearly as possible

watertight, apart from sanitary reasons, will be apparent when the capacity of the main outfall is considered, the theoretical maximum discharge from this sewer, when not working under pressure, being 501 cubic feet per minute, and no less than 33 miles of the new system of sewers contribute to the same. The total number of joints in this length of sewer will be about 90,000, and the effect of the leakage of one drop of water per second at each joint would be to bring a volume of water on to the filtration area equal to an annual rainfall of 62 inches.

Manholes circular in form 5 feet internal diameter at the bottom and 2 feet at the top are constructed at all intersections of streets, and at each junction of a branch with a main sewer; also a manhole or combined ventilator and lamphole is placed at each change of direction or gradient of the sewers, the straight line principle being adhered to with few exceptions throughout. Any part of the system may be thus readily examined, and the locality of any defect or obstruction at once detected. The outlet from each manhole is provided with a stoneware flushing block, having a ground face, and two projecting iron clips for the reception of a wooden stop-board as an arrangement for flushing. The inlets are each provided with a stoneware balance valve having an iron flap hung at the top, and in the centre of the flap a screwed spindle with ball at end, by means of which the amount of opening at the bottom can be easily arranged. The object to be attained by the use of these valves is to prevent the passage of currents of air through the sewers, and to localize and expel the gases generated in each division.

These manholes and ventilators are finished at top with a Latham's patent spiral charcoal ventilator, a full description of which may be found in 'Sanitary Engineering,' by Baldwin Latham, and also in the illustrated catalogues of the principal manufacturers of fittings for drainage works. The author does not propose to discuss in this paper the question of the effect of charcoal on the gases which are generated in and eliminated from sewage, there being many standard works of reference on this subject.

The minimum fall for the various sizes of sewers is as follows:—

27 inch	1 in 1200
24 „	1 „ 900
18 „	1 „ 900
15 „	1 „ 700
12 „	1 „ 500
9 „	1 „ 300

and the whole of the sewers will be self-cleansing, as the minimum velocity in any sewer when running half-full will be 118 feet per minute.

Flushing wells are constructed at various points on the system, the points selected being such that a sufficient supply of subsoil water may be obtained for flushing purposes, and as large a district as possible be under the influence of the well. These flushing wells are constructed in a similar manner to the manholes, with the exception of the bottom works being laid dry to allow of the accumulation of the subsoil water in the well. They are connected to a manhole on the sewers by a line of pipes provided with a sluice valve, on opening which the flushing of the sewers is easily and readily effected.

The pipe sewers at all crossings under railways or rivers are constructed of cast iron, and the brick and concrete sewers are strengthened by an additional ring of brickwork.

The cement used on the works is the best Portland. No cement is used that is incapable of bearing a tensile strain of 350 lbs. to the square inch when tested on a section having an area of 2¼ square inches, after seven days' immersion in water. An Adie's cement-testing machine is used for testing the briquettes.

The proportions for the concrete are six measures of clean gravel and sand to one measure of Portland cement; and the cement mortar, two of clean sand to one of Portland cement.

The pumping machinery, manufactured by Messrs. Hathorn, Davey, and Co., of Leeds, comprises a pair of horizontal rotative condensing pumping engines. Each engine and pump is capable of lifting 7500 cubic feet of sewage 20 feet high per hour, when working at not more than thirty revolutions per minute, in addition to driving the gearing for one chemical-mixer and one pump for the filter presses, the use of which will be described hereafter.

The steam cylinders are 12 inches in diameter, stroke 20 inches, fitted with slide and expansion valves. An air pump and a condenser self-contained in one casting are provided for each engine, worked from the end of the engine piston rod. The boilers are of the Cornish type, diameter 5 feet 3 inches, length 14 feet; flues, 2 feet 9 inches diameter. The fly-wheels each weigh 1 ton. The main pumps are similar to those designed by Mr. Baldwin Latham for the Dantzic Sewerage Works; each pump having a piston and plunger 22½ inches and 16 inches in

diameter, with a stroke of 20 inches, the pumps being worked directly from a disc on the end of the crankshaft.

There are two filter presses for the consolidation of the sludge, one of Needham and Kite's, and one of Johnson's.

The sewage from the high and low level sewers will be received into the tanks within the pumping station, and after being filtered through coke, will be conveyed, by means of properly constructed main and subsidiary carriers, on to the filtration area; the deposited sludge being subsequently treated by chemicals and consolidated by the filter presses.

The intermittent filtration area for the final reception and purification of the sewage consists of an area of land 28 acres in extent. The character of this land varies considerably, being composed of alluvial deposit overlying the London clay, the constituents of the deposit being beds of gravel and sand, marsh clay, and peat. The depth from the surface of the ground to the London clay varies from 3 to 17 feet. Subsoil drains for the reception of the purified effluent will be laid at the requisite levels. The impervious beds where necessary will be burnt into ballast or removed, and suitable porous material substituted down to the level of the subsoil drains. The purified effluent will eventually flow into the river Wandle.

The whole filtration area is enclosed by a clay puddle wall 2 feet in thickness, the excavation for which has been taken down 1 foot into the London clay. It effectually prevents the passage of any water either from the river Wandle or the surrounding waterlogged strata into the filtration area.

An artesian well has been sunk at the pumping station for supplying the water required for the condensers and for other purposes. This well is 6 inches in diameter, lined to a depth of 200 feet with cast-iron pipes, fitted with wrought-iron flush collars, the bottom pipe being provided with a steel shoe. The well is bored to a total depth of 230 feet through the following strata:—

Alluvium	12 feet.
London clay	80 „
Woolwich and Reading beds	40 „
Thanet sand	47 „
Into the chalk	51 „

Depth to chalk 179 feet. The volume of water flowing from the well (which is derived from the chalk) has remained constant since the completion of the boring. The yield is at the rate of 5·79

cubic feet per minute, or 52,100 gallons per 24 hours, and the temperature of the water 54° Fahr.

These works were designed and are being carried out by Mr. Baldwin Latham, M.I.C.E., as Engineer in Chief, the Author acting as Resident Engineer.

The total amount of the contract for the whole of the specified works is 74,708*l.*, the contractors being Messrs. B. Cooke and Co., of Phœnix Wharf, Battersea, their representative being Mr. T. Wilkinson.

DISCUSSION.

Mr. H. Oliver Smith thought that the great feature of the paper was the watertight character of the sewers, but he found no mention of the head of water over the sewer. Assuming that the temporary pump was stopped, and the water rose to its normal height, he would ask what would be the height of water in the soil over the new sewer? and had the author found that the tarred gaskets and the cement rendered the pipes practically watertight? Then if as was stated with respect to the brickwork, there were rings of brickwork with a collar of cement, he wished to know whether there was a collar joint and the work simply done with a trowel, or whether there was a coat of rendering which was allowed to set before the inner course was put in? He also wished to know whether it had been found in every case, after the pumping was suspended, that the sewers were to all intents and purposes watertight.

Mr. Baldwin Latham said that it was with very great pleasure that he found the Association assembled at his works. He hoped that they would criticize his works as much as possible, as it was only by criticism that they were led to further improvements. He had had a very large experience in the construction of sewers, and without reflecting upon any of his former works, he could say that he did not think that he had ever designed or carried out a more perfect system than that now in hand for the Rural Sanitary Authority of Croydon. In fact a few years ago the importance of making sewers watertight was entirely overlooked. The importance of sewers being practically impervious was beginning to be recognized, and it was seen that subsoil water might be easily fouled by defective sewers, so that a system of sewers when brought into a district might become an injury instead of a benefit. The success of

a sewerage works of a district depended not only upon the care and skill of the engineer in designing them, but also in a great degree upon the care of the men who had to construct the sewers, and who were directly responsible for the work. He had in some cases met with contractors who, as soon as his back was turned, when constructing combined brick and concrete sewers, would depart from the specification and fill in the trenches omitting the concrete, so that when the sewers were subsequently examined they were found to be in a state of leprosy. But nothing of the sort took place in the present instance. He had never in the whole course of his experience found contractors who were more anxious to perform their work than Messrs. Cooke, who were carrying out these works for the Croydon Rural Sanitary Authority. In many instances he had suffered in professional reputation through having to deal with scamping contractors. Those who were town surveyors knew how very important it was that sewerage works should be thoroughly executed; and he might here say, in reference to the qualifications and the examination of town surveyors, he was one of those who were of opinion that if they wanted to judge of the ability of a town surveyor, they should go to the district in which he was located, and see whether that district had improved in its sanitary status while he had been the director of its sanitary works. He should now mention that the materials used in the works they would inspect that day were all of the very best quality. It was impossible to construct good works without good materials. The pipes used were supplied by Doulton and Co. The resident engineer and inspectors did not allow any irregular or ill-shaped pipe, or pipes of improper thickness, or any unsound pipes or doubtful pipes to be used. With regard to the principle upon which the works were carried out the district had been divided into high and low levels as stated in the paper. The sewage of the greater proportion of the district was collected by the high level system of sewers. There was however a low portion of the district which drained to the Beverley Brook, which was in another watershed, and which for the purpose of economy it was necessary to bring back to the main outlet, which was in the Wandle watershed, the larger portion of the district having its natural outlet to the Wandle, and a comparatively small portion having its outlet to the Beverley Brook. The Beverley Brook therefore had to be drained by a low level sewer, the sewage of which required to be pumped. At present the district was not populous, but the roads had to be formed, and there was no doubt

but that when the system of sewerage now in progress was completed it would add immensely to the value of land and other property, especially as the district had such wonderful facilities of railway communication with the metropolis. The low level sewage was brought by gravitation to the building in which they now met, where there was a pair of engines for the purpose of pumping it. It would be stored in a tank sewer when the pumping was suspended. The pumps would lift the sewage to the high level system which was immediately outside the building. Then the sewage of both systems would flow through the tanks. It was not intended to treat the sewage itself by chemicals, although provision had been made in the design of the works to do so if it should ever be found necessary to use chemicals. There was a mixing apparatus at one end of the building and a pipe was directly laid on to the sewers outside. By this means the chemicals could be passed into the sewage while it was still in the sewers. He had however found it undesirable to use chemicals, because the effect of chemicals was to a certain extent to pickle the sewage, and to render the subsequent treatment by the land more difficult for oxidation. The work the land had to perform was retarded by the use of chemicals, and moreover chemical treatment was an expensive process. If chemically treated sewage which had passed through the earth was smelt at the outfall, it would often be found that the earth had not undone the mischief which the chemicals had done and that the escaping liquid smelt strongly of the chemicals. On the other hand sewage applied to the land in its natural state was readily oxidized. The difficult part of the process of sewage treatment was the dealing with the sludge. Those who had had experience of sewage sludge were aware what a nuisance it became, especially sludge which had not been treated with chemicals. Such sludge would never drain dry. If it remained for twelve months in a heap a dry crust would form on the outside whilst the interior of the mass would remain moist. As these sewerage works were located in a populous neighbourhood it would be undesirable to allow an accumulation of sludge to lie about, owing to the nuisance which would be created; consequently, the tanks and all works connected with the treatment of the sewage and sludge were placed under cover, and the tanks were so designed that the sludge could be turned out of them into a subsidiary tank. From the subsidiary tank it went directly to a well in which there was an agitator. It was there intended to be mixed with lime which destroyed the mucous property of the sludge, and

enabled it to pass through the filter press and be brought out in a compressed form, in which it could be carried away. The method for consolidating the sludge was this: There were two cylindrical receivers made of wrought iron, and these were connected with a pair of air pumps which would alternately exhaust and compress air. If one of the receivers was exhausted of air it would act like the apparatus adopted on the Continent for emptying cesspools; for when a vacuum was obtained within the receiver and the valve communicating with the sludge pit was opened the sludge rushed into the receiver. Then when the valve was closed and air was pumped into the receiver upon the top of the sludge, the sludge would then be driven out of the receiver through the filter presses at a high pressure, which would in turn cause the solid matters to remain in the chambers in the filter press and the liquid portion to pass away. When the press was full of solid sludge, it was opened, and solid cakes of sludge dropped out and might be readily carried away. They did not suppose that they should get any profit out of the undertaking. In fact all that they had been aiming at was to deal with the sludge so that it should not be a nuisance to their neighbours, and he believed that in that respect they would succeed. However when the works were in operation he should be glad to see the Association again, and he thought that he should be able to show them that the works were a success. With regard to the separation of the sludge from the liquid portion of the sewage, it would be seen that the tanks were divided by a number of partitions. In the first division of the tanks there was a dip board, and the sewage had to pass under this board, so that the floating matter was held back. The liquid then passed over the first division wall, and under another division and over another, and then it passed through two perforated walls forming a chamber in which coke or other suitable material was placed before it passed on to the land. The land was all deeply drained and the filtration would probably average about 5 feet. It was proposed that the sewage should be distributed under the surface of the upper plots only so that none of it would be seen immediately near the populous part of the district. For that purpose porous pipes were laid under the surface, the ground being first removed, and the area between the pipes was filled in with burnt ballast so that the sewage might be distributed over the surface, and then it would filter through the ground to the lower subsoil drains. It was hoped that in that way they would entirely obviate any nuisance. In

fact if the sewage was not seen nobody would find fault with it. The only objection he had found in treating sewage was entirely one of sentiment. When people saw sewage or knew that it was near them they thought that there must be an offensive smell. He had never found any great nuisance arising from a sewage farm if it was only moderately well conducted. After the sewage had been passed on to the land and through into the drains it would escape into the old channel of the Wandle. That channel fortunately had its outlet lower down the valley so that they had been able to get a deep outlet without any very great expense. Of course the land would be cultivated but the scheme did not contemplate the realization of any profit, although there was no doubt that some return would be realized from the land. It was estimated that when the works were completed—and the whole district would have to contribute—the rate would not exceed 15*d.* in the pound. If the present system had not been adopted the only alternative would have been to join the West Kent scheme which went to Parliament last Session, and which was authorized to levy a rate of 1*s.* 9*d.* in the pound upon any district which used their sewers. If the Croydon Rural Sanitary Authority had joined the West Kent scheme, they would have had to drain their district and pump all the sewage to a considerable elevation, and then pay 1*s.* 9*d.* in the pound for permission to use the outfall. The adoption of the scheme which was now in hand reflected very highly upon the discrimination of the chairman and other members of the Croydon Rural Sanitary Authority, for the matter was long discussed and great pressure had been brought to bear upon them to join the West Kent scheme. By entering upon a scheme of their own the Croydon authorities had escaped the troubles and dilemmas which had arisen in connection with the West Kent scheme, and the result would be that the district would have one of the best systems of sewerage that had ever been carried out. As to the water-tightness of the sewers, if the many miles of high level sewers which had been already constructed were inspected it would be found that they were perfectly watertight even within 9 or 10 feet of the channel of the Wandle, on a gravel soil, and where the water lay at a level of about 12 feet above the sewers. Careful gaugings of the water coming down day by day had been made, and it had been found that instead of the quantity increasing it diminished. He would not say that if they went into one of these new sewers that they would not see a little dampness on the inside, but they would not find any dropping or leakage in any part of the work.

The fact that the sewer had been so made reflected very favourably upon the contractors, and also upon the inspectors and resident engineer who were superintending the work. The works were severely tested every day. A record was kept daily of the quantity of water which the sewers were yielding. With regard to the details of the scheme, the author of the paper had very fairly described them. Another point of novelty to be found in these sewers was the balance valve, which was used in preference to the old shackle valve which he had used formerly. It would be seen that the balance valve lay in the opposite direction to the old shackle valve. By the adjustment of the ball which altered the centre of gravity, the valve might be made to open or close with the slightest breath of air. On the other hand if the ball was screwed closely up to the plate it required some pressure to open it. The balance valve was not more costly or troublesome to make than the old shackle valve, and it afforded a means by which they might control currents of air in the sewers. As was shown shackle valves led to the accumulation of matter in the drains or sewers immediately behind them, but the balance valve did not allow of such accumulation and was found most efficacious and when properly adjusted answered its purpose admirably. The flushing valve which he used appeared to be something after the type of a valve described in the first paper, and had simply a ground face. It simply required a board put down in front of it. That board was held against the face by studs of iron, and it could be removed when required. All the manholes in this scheme were flushing stations, and they could either be filled with water from water-carts as suggested in the first paper, or by damming up the sewage, or filled by means of the wells which would be provided in various parts of the district. The very fact that they got their flushing water from the soil in which the sewer was laid, showed that to a large extent the subsoil of the district was surcharged with water, and the more necessity there was for making the sewers watertight. If the sewers were not watertight none of the flushing apparatus would act as they would get no water for the purpose. The puddle wall round the area of the filtration works had answered its purpose admirably. By its means they had been able to shut out the river Wandle on the one side and the Brook on the other. It would be seen from the many trenches that were opened that they had been able to reduce the water 7 or 8 feet over the whole of the filtration area. The great trouble in

regard to the filtration area was that they had met with beds of peat, which was a most objectionable material for filtering, as it held a large quantity of water. He did not know whether it would become necessary to remove the peat, but he did not propose to do anything with it until the area was brought under filtration and experiments had been made upon it.

Dr. JACOB wished to ask Mr. Latham a question which bore upon a subject of great importance from a medical point of view. These sewers being laid in a waterlogged soil, and being themselves watertight, as for many reasons they ought to be, would it not have been desirable to lay an open-jointed subsoil drain under the sewers for the purpose of lowering the level of the subsoil water? Medical men acting in the capacity of officers of health had found that the health of a district was always improved the moment that the level of the subsoil water was lowered. The great drawback of watertight sewers was that they did not lower that level. He was acquainted with many towns in which watertight sewers were laid in a waterlogged soil, the subsoil water-level being lowered by means of an open-jointed drain placed under the sewer and laid in the same trench. This arrangement produced a perfect result, and gave a bed of 10 or 12 feet of dry soil under every house, such an arrangement being most essential to health, while the water-tightness of the sewer prevented the escape of filth into the soil. He heartily congratulated the Croydon Rural Sanitary Authority upon the excellent scheme which they had adopted. If all the rural sanitary authorities would be as energetic in sewering their villages and districts, their medical officers would be encouraged, and the effect upon the health of rural districts would in a few years be most gratifying to all concerned.

Mr. BALDWIN LATHAM replied that in certain districts it was of course desirable that the water-line should be lowered but in this instance the fall of the district followed the fall of the river Wandle, and the soil consisted for the most part of a drift gravel which was very impervious; and the lowering of the subsoil water would really mean that they must construct a subterranean river at a lower level. There was another point. There were thirty-six mills upon the river Wandle, which showed how rapid was the fall of the valley. The subsoil water which in ordinary districts might be stagnant, had in this case an immense fall, and so there was a rapid movement in the water. Therefore looking at it from a sanitary point of view, it might be regarded as an unpolluted stream continually

flowing through the soil, and washing away any slight impurities which might pass from the surface. He believed that it was admitted by all who paid attention to the subject that the health of the district was most materially enhanced by the permanence of this subterranean water-level. It was only in districts where there was great fluctuation between the highest and lowest water-levels that typhoid and other diseases of that class became rife. In this district there was a pretty uniform level, for the mills upon the river had a tendency to make the water-level uniform; and it was a fact that there was not a district in the whole of England so free from fever as that of the Croydon Rural Sanitary Authority. As to the placing of a subsoil drain under the sewer proper he had never yet in the course of his experience found a drain put in such a position. Sooner or later it would undermine the sewer above and lead to its destruction. The movement of the water in the subsoil drain would carry away the fine materials of the strata in which the sewer was placed, and produce an evil which they in Croydon had been most anxious to guard against.

Mr. Buckley said that there was one question which he should like to ask the author of the paper. It had been stated that the sewage water, after it had been clarified of the sludge and taken on to the irrigating surface, was carried in various pipes a little below the surface of the ground. He should like to know at what depth below the surface those pipes were laid and whether if the ground was to be used for the purpose of cultivation, any advantage that might otherwise be gained from the use of the water was not lost? Did not all the valuable properties of the water percolate into the ground, none of them rising to the roots of the vegetation at the surface? One point which must be very interesting to them all was that there appeared to be no attempt made to get any profit out of the sludge or the material taken away. He believed that a very great mistake which was often made by sanitary authorities was to sacrifice the efficiency of their works to an attempt to make money out of them. Indeed he had heard Mr. Baldwin Latham say the other night that he thought it was impossible to make any profit out of sewage and that it was practically worthless. If sanitary authorities would try to do their duty, instead of trying to make money out of a sewerage scheme, it would be to the great advantage of everybody.

Mr. Baldwin Latham said that there was a great difference between irrigation proper and filtration. In irrigation where

there was a large area to be treated with sewage the fertilizing matters were supposed to be absorbed by the soil and the plants on the surface of the soil. There was a totally dissimilar state of things in the case of filtration. In filtration they had simply got to seek the destruction of the organic compounds of the sewage by bringing them in contact with the earth, which was a porous substance containing air in its mass, and therefore capable of acting as an oxidizer. Any porous substance would produce oxidation if it would hold air or hold oxygen in a nascent form. That is a form in which it would readily combine with organic matter. In the filtration scheme it was merely an incidental circumstance that they were able to use the surface of the filtration area for the cultivation of a crop. Such cultivation was not the main object. They did not look to the crop at all for the purpose of removing the polluting matter, and if the filtration scheme required that the drains for distributing the sewage should be 18 inches or 2 feet below the surface, they must be put there, although they might be out of the reach of the crops above. There was a great difference between utilizing sewage and simply burning it up by a slow process of combustion such as the filtering area produced.

The PRESIDENT, in closing the discussion, thanked Mr. Baldwin Latham for receiving the Members of the Association, and expressed the obligation which the Association was under to him and to Messrs. B. Cooke, and Co., the contractors, for their courtesy.

DISTRICT MEETING AT MERTON,

December 5, 1879.

NOTES ON IRONWORK.

By GRAHAM SMITH, Assoc. M. Inst. C.E.

The branch of science which enables the engineer to determine the theoretical amount of strain in the members of any proposed structure may be said to appeal directly to ordinary intelligence and to be on the whole simple. The science however depends upon data and conditions the exact influence of which can never be determined in actual practice. It is proposed therefore in this paper to consider briefly some of the practical questions which affect theoretical deductions, and the design, efficiency and economy of ironwork structures generally. The precise conditions under which ironwork will be constructed and worked being indeterminable, it becomes necessary among other matters to have some knowledge or workshop practice and routine in order to determine the proper limits and importance to assign to theoretical results.

In taking out strains it is usually assumed that each member has a normal length whatever the amount of strain to which it is subjected, and that its conditions are the same as they would be were it free to turn in a plane about its extremities. Both of these assumptions are to a certain extent erroneous. So far from any bar having a normal length, that is being perfectly rigid, it may be taken for granted that directly any piece of iron is subjected to a tensile or compressive strain its length is varied accordingly. Likewise no member of any structure is perfectly free to turn in a plane about its extremities. In English practice junctions are frequently made with innumerable small rivets which render them to all intents and purposes rigid. In America however pin connections are employed to a large extent, and undoubtedly with pins and eyes properly proportioned efficient joints may be made, and with simple arrangement of parts theory

be more closely approached than with our complicated systems with riveted joints.

Variations in the temperature of the atmosphere likewise materially affect the strains in iron structures. When constructing an iron bridge a camber is given to it so that when loaded it may assume a straight line instead of exhibiting signs of apparent weakness by sagging. While testing the bridge it is usual to measure the camber as the load is put on, and it is not uncommon to find that on a warm day the camber is greater than it was the evening before, notwithstanding that a larger amount of load has been put upon it. This anomaly is due simply to the sun warming up the top flanges, so causing them to extend, whilst the bottom flanges do not extend to a similar extent owing to being protected from the sun by a platform or the load upon the bridge. It has been ascertained that a variation of temperature in iron of 15° Fahr. will produce the same effect as one ton actual load per square inch; therefore a change of 82·5° Fahr. will produce the same effect as 5·5 tons per square inch actual load, which is greater than the amount of strain supposed to be put upon any bar when under its full working load. Now although the difference between the extremes of temperature in this country may be estimated at 82·5° Fahr., the extreme temperatures only act during a short portion of each twenty-four hours, and so owing to the mass of iron and other circumstances the temperature of the structure is seldom the same as that of the atmosphere, consequently the iron is not affected to the full extent just mentioned. There are of course many positions which will at once suggest themselves where the temperature is tolerably uniform throughout the year, and where accordingly no provision need be made for expansion and contraction due to changes of temperature. In exposed positions in this country an allowance of $\frac{7}{16}$ of an inch in each one hundred feet should be made if it is wished to eliminate strains which it has been shown may be of considerable amount. Edwin Clark has placed it on record that half an hour's sunshine has more effect on the tubes of the Britannia Bridge than the heaviest rolling loads or the most violent storms.

Questions of the foregoing nature having been considered and the strains upon the various members of the proposed structure having been determined within reasonable limits, it becomes necessary to arrange the material to meet them. It is in doing this properly and economically that the art of designing ironwork

consists. In all designs every endeavour should be made to employ iron of such dimensions and weights that it may be easily procured in the open market, and require only such workmanship as can be cheaply and readily performed. By attention to these points economy will be more surely attained than by the saving in the weight of iron which may be effected by adhering more closely to theoretical refinements. As an instance of this it may be stated that the actual weight of a plate girder is always very much in excess of its theoretical weight, and it is rarely the lightest form of girder which it is possible to design to carry a load; it is yet generally the most economical type to adopt for small spans, owing to the uniformity of its parts and the simplicity of its manufacture. While mentioning plate girders it may be well to state that although the theoretical economical depth of all girders depends upon their description, the loads to be carried and a variety of other circumstances, the depth of a plate girder is often fixed by one consideration alone and that of a practical nature quite beyond the control of the designer. It is simply the fact that plates cannot be rolled at ordinary rates over 4 feet 6 inches in width, so that the maximum depth of ordinary plate girders is fixed at 4 feet 6 inches. If this depth is exceeded it becomes necessary to plate the web vertically, which will enhance the cost of the work to an extent exceeding the saving likely to result from conforming more nearly to any greater depth which theory might dictate. In arranging the flanges, although theoretically the section of metal should be reduced at certain points, it is generally desirable when a limited number of girders are to be made from one design to keep the plates as nearly uniform in thickness as possible, rather than to vary their thickness so as to approach more closely to the amount of metal required to meet the strain. However where a large number of girders are to be constructed from the same design the plates may be varied in thickness without increasing in any way the cost of the work, as the plates can be ordered in batches from the rolling mills and relegated to their respective girders in the manufacturer's yard.

At one time much of the iron employed for girder and bridge building came from Staffordshire, consequently specifications were prepared in such a manner that iron from this district might comply with their stipulations. These specifications have been copied and recopied even up to the present time notwithstanding that Staffordshire iron is now rarely put into ordinary ironwork, for

the reason that the sizes of the iron supplied from this district are small when compared with those from the north country. This is owing to the Staffordshire mills working with plant which was put down many years since, whilst the ironworks in the Cleveland district are provided with more modern machinery and improved appliances. A South Staffordshire plate to cost the ordinary market rate must not be over 4 cwt. in weight, 15 feet in length, and 4 feet in breadth, and about 30 superficial feet in area; whereas Cleveland plates can be procured without additional cost up to 21 feet in length, 4 feet 6 inches in width, and 12 cwt. in weight, providing the area does not exceed 56 superficial feet. Although plates from the latter district may be obtained possessing as great a tensile strength both with and across the fibre as those from Staffordshire they are not as a rule equal to the latter in toughness. Extra care should therefore be taken to test and thoroughly ascertain the quality of the iron, as it is sometimes very brittle. No attention whatever should be paid to "Brand," as it is no criterion by which to judge of the qualities of iron usually employed for the construction of ordinary ironwork. A very fair specification for girder iron is 20 tons per square inch and 6 per cent. elongation with the fibre; 18 tons per square inch and 3 per cent. elongation across the fibre for plates; 22 tons per square inch and 9 per cent. elongation for L and T's; and 24 tons per square inch and 15 per cent. elongation for rods and bars. These elongations ought to be taken on a testing section of uniform width for a length of $6\frac{1}{4}$ inches. In a length of $6\frac{1}{4}$ inches there are one hundred sixteenths of an inch, so that each $\frac{1}{16}$ elongation after testing represents 1 per cent. In preparing all samples for testing they should be drilled out of the plate, angle or bar, and be either chipped or slotted to the required dimensions and all tool marks carefully filed out, and the parallel portions should run in with curves of large radii to the portions through which the pin holes are drilled. In the event of there being the slightest shoulder at either of these points, it will have the same effect as a nick in the iron which will generally render worthless the test for both tensile strength and elongation. With a little experience the quality of a plate may be determined to some extent by breaking the corner off over an anvil, and by inspecting the punchings from the plates. If the iron is brittle and untrustworthy the punchings will show cracks in all directions, if the punch be working as ordinarily with a little clearance, whereas if the iron is good and reliable slight

cracks only will be perceptible all running in the direction of the fibre. Whilst these workshop tests can be carried out in the manufacturer's yard by the inspector during the progress of the work, all tests requiring to be made with hydraulic presses or steel-yards should be conducted by independent authorities such as Mr. Kirkaldy. After the material has been tested and passed and the structure put together it becomes necessary to apply a proof load, which consists of gradually placing on the structure a weight somewhat exceeding its working load. This is requisite in order to ascertain if the workmanship is up to the proper standard. It must however be always remembered that a proof load is no test of the strength of the structure or the quality of the material. If the iron is hard and brittle it will give less than a material of more desirable quality and the structure will apparently be stronger, but it is needless to state that such is not the case. Again any part may be on the point of breaking and yet not yield sufficiently to materially alter the deflection. Likewise although a structure may stand the application of a proof load at the time of testing, it does not follow that it will stand repeated applications of loads of even less amount than the proof load. Fairbairn's experiments carried out many years back demonstrated this fact. He found that when the strain on the iron of a beam was between 6 and 7 tons per square inch, the beam sustained an unlimited number of applications of the load producing this strain; but when the load was increased so as to put a strain of from 8 to 9 tons per square inch on the iron, the beam failed with a comparatively few applications of the load.

There are a variety of other matters of detail to be considered in designing and constructing ironwork but time will not permit of their being now dealt with. The author will therefore only add in conclusion that the views herein expressed have previously been made public in a somewhat different form in the scientific press. This will account for any apparent similarity of ideas which may exist in this paper and the articles which were of course unauthenticated.

As the afternoon was far advanced, and the works had yet to be visited, there was no discussion on this paper.

DISTRICT MEETING AT DEWSBURY,

March 19, 1880.

SEWAGE DISPOSAL AT WEST DERBY.

By E. H. ALLIES, Assoc. M. Inst. C.E.

The sewage of the greater part of the population of the township of West Derby, which is a suburban district of Liverpool, until the year 1872, was allowed to discharge into Tue Brook, and pollute the entire course of that stream. An injunction in Chancery was at that time obtained by a gentleman, through whose property the polluted stream ran, to restrain the Board from discharging its sewage into the stream. The Board had therefore to consider the question of disposing of the sewage of the district without causing a nuisance, and various schemes of sewage disposal were discussed. One of the schemes proposed was that the sewage should be carried down to the mouth of the Mersey, and discharged near Rimrose Bridge, below low water-mark in the tideway of the Mersey. This scheme, however, fell through, owing to the opposition of the Waterloo and Great Crosby Local Boards, and all hopes of obtaining an outlet seawards being abandoned, it was finally determined to dispose of the sewage by irrigation for agricultural purposes. Under the advice of Mr. Bateman, C.E., and the late Mr. Orridge, C.E., then Surveyor to the Board, it was decided to acquire the land at Fazakerly which now forms the sewage farm. It having now been in operation for some years, a short description of the farm, the works in connection therewith, and the results obtained, may be of some interest to the Members of the Association of Municipal and Sanitary Engineers and Surveyors.

A provisional order was obtained in the year 1870, the land was purchased, and under the direction of Mr. W. Hope laid out for irrigation. The Board obtained loans amounting in the aggregate to 63,350*l.*, for the purpose of buying the necessary land,

laying it out, and constructing the works. The area of land purchased was 207 acres, and the sum paid for this was 36,134*l.* 18*s.* 7*d.*, being equal to 174*l.* 11*s.* 3*d.* per statute acre. The amount paid for laying out and developing the farm was 16,948*l.* 18*s.* 11*d.*, being equal to 81*l.* 17*s.* 7*d.* per statute acre; and the total cost of the tanks, engines, pumps, boiler and engine-house was 6717*l.* 18*s.* 3*d.*; making a total of 59,801*l.* 15*s.* 9*d.*

The soil which had to be operated upon was not all of the most suitable description for sewage farming, about two-thirds of it being clay and the remainder a sandy loam. The whole of the land which was to receive sewage was drained to an average depth of 3 feet, the effluent water discharging into the River Alt.

The population of West Derby is about 34,000, but the sewage of some 7000 of this number is discharged into the Liverpool Corporation sewers. The West Derby Local Board have therefore to deal with the sewage of a population of 27,000 persons, whose number is constantly increasing. To convey this sewage to the farm, two main outfall sewers were found to be necessary. The western outfall sewer, 12,775 yards in length, carries the sewage of some 20,000 persons, and discharges it by gravitation over that part of the farm irrigated by it. It is a brick culvert 5 feet 3 inches × 3 feet 6 inches at its largest part, with gradients varying from 1 in 1056 to 1 in 211, the estimated daily flow of sewage being 600,000 gallons. The eastern outfall sewer, which conveys the sewage of about 7000 persons, is 11,033 yards in length; like the western outfall sewer, it is a brick culvert 4 feet 6 inches × 3 feet, with a daily flow of sewage of 210,000 gallons. It discharges its sewage at the farm at too low a level for it to flow over the land; and it is therefore received into two tanks, which are of a sufficient capacity to contain the ordinary flow of sewage of the district from Saturday evening to Monday morning, and it is thence pumped on to the land. The tanks are 156 feet long, 21 feet wide, 19 feet 6 inches deep, are two in number, covered with 14 inches brick semicircular vaulting, and the sewage, which discharges from the sewer into catch-pits, is thence turned into either tank at pleasure, a grating at the entrance retaining any solid matters. The tanks not only act as receivers for the sewage during the time it cannot be pumped, but also as settling tanks to allow the sludge to deposit. This, however, is a questionable advantage, as the sludge has to be constantly cleared out of the tank, and if the sewage were not allowed to stagnate, the whole

could be passed through the pumps and on to the land, as in the case of the other outfall sewer.

The sewage is taken from each tank by a floating pontoon grating, which rises or falls with the sewage, the object of this arrangement being to keep the sludge from getting to the pumps. The pumps, which are by Tangye Brothers, are three in number, and each capable of lifting 25,000 gallons of sewage per hour, to a total height of 40 feet, 17 feet 6 inches of this height being below the ground level at the pumping station. The steam cylinders are 12 inches diameter, pump plungers 10 inches diameter, with a stroke of 24 inches, and the suction and delivery pipes are 8 inches. The pumps are all similar in design, and so arranged that each pump may be worked independently, so that either may be stopped for repairs without in any way interfering with the working of the remainder, which can be run, if necessary, at a greater speed, so as to raise an increased quantity of sewage. They are supplied with steam from a horizontal boiler 24 feet long, 5 feet 1 inch diameter, which is fed with water by a Cameron's steam pump. These pumps have since their erection in 1875 given great satisfaction.

The sludge which accumulates at the bottom of the tanks is cleared out from time to time, a large portion of it being lifted by a 6-inch chain pump, worked by a ploughing engine, which is stationed at the tanks for that purpose, men being sent into the tanks to stir the sludge and sweep it towards the pump. The remaining part of the sludge which cannot be reached by this means is removed by hand labour, and this has to be done about once in the year. The sludge is spread over parts of the land near the tanks, and is dug in; this is found to be the most advantageous method of getting rid of it. The main carriers throughout the farm are of concrete, of a square section and 18 inches in width; the minor carriers or distributors are formed of the soil, and attended to by men who regulate the supply of sewage as it is required.

The effluent water after passing through the soil is discharged by the subsoil drains into the River Alt and other streams which bound the farm. This water is very clear, and is fit to be turned into any watercourse; no complaints have been made of any pollution of the stream below the farm. If time had permitted, the author would have given the results of analysis of effluent water taken in dry and wet weather, as he believes they would

compare favourably with effluent waters from most sewage farms, and a comparison of them with the results obtained elsewhere would be of interest.

The principal crops which are grown on this farm are rye grass, mangolds, potatoes, cabbage, clover and rye grass, wheat, oats, and barley, a large breadth being always laid down in rye grass, which is cut from six to seven times in the season. The proximity of a large town like Liverpool offers a good market for all sorts of produce, but crops are frequently sold to customers at a much greater distance.

There is no stock kept on the farm other than the horses required to work it. The whole of the agricultural work is done by ten horses, it not having been found advantageous to use a large quantity of expensive ploughing and other machinery which was purchased when the farm was commenced. It is questionable if the full profit can be got out of any sewage farm unless a sufficient quantity of stock is kept to feed off the principal part of the grass and root crops which form a large proportion of the crops annually raised. The profit made on the feeding of these crops, grown on a sewage farm where no stock is kept, of course goes into the pockets of the persons who buy such crops; and the cartage to market, which is always a very heavy item, is also lost to the farm.

The cartage from the West Derby farm to market averages about seven miles, and the carts load back with manure. The whole of this cartage and the price of the manure would be saved to the Board were stock kept, as the manure would then be produced on the spot.

This farm commenced working in the year 1872–3, but the whole of the sewage of the district was not then brought to it, nor was the whole of the land under crop. It can only be considered as in full working order since the year 1876–7, the financial year ending on the 25th of March. In the year 1876–7, the income exceeded the working expenses by 912*l.* 14*s.* 11*d.* In the year 1877–8 the working expenses exceeded the income by 48*l.* 4*s.* 4*d.*, and in the year 1878–9 the income exceeded the working expenses by 775*l.* 12*s.* 0*d.*

Thus in the last three years the income of this farm has exceeded the working expenses by 1640*l.* 2*s.* 7*d.*; and since the commencement of the farm in 1872 the income account exceeds the expenditure by 230*l.* 4*s.* 2*d.* The undertaking was

not entered into as a commercial speculation, but solely as a means of getting rid of the sewage of a district, and it must be admitted that the disposal of the sewage at West Derby has so far been a success.

DISCUSSION.

Mr. T. Hewson, in opening the discussion, asked whether depreciation of plant or interest on or reduction of capital expended either on outfall sewer or farm lands, were included in the working expenses. It was stated in the paper that a 5 feet 3 inch sewer discharged 600,000 gallons; he would inquire whether that had relation to the capacity of the sewer or the actual sewage discharged by it. The question naturally occurred to him, whether or no this sewer took the whole or any part of the rainfall of the district, and if so, whether the whole of the discharge of the sewer went upon the land. In *utilizing* land in the interests of their clients, he thought it was a moot question as to how much of the rainfall it was reasonable and proper to provide for in the farm outfall sewer. In the case of Blackburn, the lands take the discharge of a 2 feet 6 inch pipe, laid at an average inclination of one in a thousand, whilst the main outfall of their sewerage system was 6 feet.

Mr. J. Allison, in reply to Mr. Hewson's question as to whether the sewer was constructed of sufficient capacity to take the rainfall of the district, said, in the absence of any information there was no doubt that it did include the rainfall. The district comprising 7000 persons on the eastern outfall which joined the corporation sewers, and 27,000 persons of the Local Board District, would give a total of 34,000 persons, and the quantities of sewage given were 210,000 and 600,000 gallons, being equal to 24 gallons per head, which clearly showed there was sufficient capacity in the sewer to carry off the surface water.

Mr. B. C. Cross thought that the Meeting should ask the author to supply an analysis of the effluent water, as he said he would have done in his paper had time permitted. They ought to be informed also as to the nature of the land upon the farm, and a detailed list of the expenses and receipts of twelve months would add to the value of the author's communication.

Mr. Allison observed that there was one important question which the author of the paper had omitted to give the requisite information upon, viz. what quantity of sludge was deposited upon

the land at one time; was it a covering of 2 inches, or was it 4 or 5 inches in thickness over a given area? and how often was it applied to the land?

Mr. E. PRITCHARD (President) said that it could not be put on continuously, as it would have an injurious effect upon the land; the author ought to have stated in what proportions it was applied, and at what periods. It was extremely unfortunate that the author could not attend, but he was led to understand his absence was perfectly unavoidable.

Mr. J. MATTHEWS JONES remarked, that the paper opened up the whole question as to whether irrigation, precipitation, intermittent filtration, or other means of sewage disposal was the best. He had under his control a district with about the same number of inhabitants, and they had adopted the precipitation process. Their works had not cost as much as those at West Derby, and they were managing to pay off by degrees the money borrowed in the first instance for their construction. They sold their sludge at Chester to the farmers in their district, whereas at West Derby they took the manure to the market towns. It was true that it was sold at a nominal price, but if it were not got rid of in this manner it would be necessary to have a large area of land on which to place it. Their capital, cost and working expenses equalled 5*d*. in the 1*l*. on their rateable value of 144,000*l*. which included the paying off at the rate of 3½ per cent. of money borrowed.

Mr. GRAHAM SMITH said, he remembered the time when there was considerable misgiving as to the prospect of the West Derby Farm paying its working expenses; it was therefore satisfactory to find that as sewage farms go it might be said to be flourishing.

Mr. HEWSON thought it only right to warn Mr. Smith against making a statement of that nature, for where there was no rent, &c., it would not be a wonderful circumstance if a sewage farm were made to pay.

Mr. PRITCHARD, in closing the discussion, thought that the salient points of the paper had been attacked very ably by Mr. Hewson. The weak point in the paper was its want of exact information. Something was omitted which ought to have been supplied, particularly when they were informed that a 5′ 3″ × 3′ 6″ sewer was constructed for the removal of sewage equal to 600,000 gallons per day, or an amount which could be removed by a 12-inch pipe sewer with a good gradient. It appeared to him

important and necessary that it should be stated by the author whether the rainfall was taken to the farm, or whether it was diverted into the water-courses. It was also desirable that an analysis of the effluent and sub-soil water should be given. He had formerly been strongly in favour of irrigation by itself, but recently his opinion had been somewhat shaken. He did not believe in any hard and fast rules being made as to the treatment of sewage, as it was entirely governed by local circumstances. Where there was a tidal river, precipitation processes might be all that was necessary for the treatment of the sewage to be discharged therein. He was somewhat surprised to hear that Tangye's pumps were being used for the removal of the sewage at West Derby. It was an excellent machine for certain purposes, but he did not consider it a good pump for the removal of sewage, as the sand which in nearly all cases is found in sewage would have an injurious effect upon its working parts. He should like some statistics to be given as to the working and repairs of the pumps. He thought it right to inform the meeting that he had just been informed by Mr. Smith, that the author had prepared his paper in some haste in order to meet the views of the Secretary.

Mr. J. LOBLEY said that he believed Messrs. Tangye Brothers themselves did not recommend their ordinary direct-acting pump for lifting sewage in large quantities to a low height. That firm had just completed a contract under his (Mr. Lobley's) direction, and they had erected two 15-inch centrifugal pumps of their own type.

Mr. E.H. ALLIES replied to the discussion in writing, as follows:—The figures given as *working* expenses did not include depreciation of capital, or reduction of sums spent on the farm. These sums would be paid off in 30 years at 6 per cent., including interest and instalment.

The volume of sewage given was the actual amount of sewage proper dealt with, and did not include the rainfall. As much of the rainfall as possible was kept out of the sewers, and there is a storm overflow which somewhat relieved one of the main sewers; but practically the whole, or nearly the whole, of the rainfall was admitted into the sewers, and had to be dealt with at the farm. The soil consisted of two-thirds clay and the remainder sandy loam. It was difficult to give the proportion of each more distinctly, as patches of clayey and sandy soils alternate on some parts of the farm. The author did not think it was advisable to give here a

detailed list of the expenses and receipts of the farm for twelve months, but would endeavour to reply on this point to any member who might personally apply to him.

The quantity of sludge put upon the land is nothing like 2 to 4 or 5 inches in thickness. It was pumped from the tanks and allowed to dry before being spread over the land and dug in. It was only applied lightly to the soil, which would be choked if a large quantity were put on at one time. The tanks were cleaned out about once in the year.

Mr. J. Matthews Jones seems to be under some misapprehension as to taking manure to the town at West Derby. The author stated that the carts loaded *back* to the farm with manure. The cost of sewage disposal at West Derby at the present moment, including interest on loans and instalments, is $5\frac{1}{8}d.$ in the pound on the rateable value, which is 181,636*l.* This payment will cease in about twenty-two years, and the Board will then own a freehold property of 207 acres.

With regard to Mr. Lobley's remarks as to Tangye's pumps, the author does not mean to say that he would always recommend such pumps for raising sewage, but that these pumps at West Derby have been found satisfactory. Perhaps this result is partly owing to the arrangement for taking off the sewage from the tanks described in the paper.

DISTRICT MEETING AT DEWSBURY,

March 19, 1880.

THE SANITARY CONDITION OF DEWSBURY, AND ITS SEWERAGE WORKS.

By BEN. C. CROSS, C.E.

In welcoming the Members of the Association to Dewsbury, the author wished to impress upon them that they had come into a district where natural beauty had been destroyed by the progressive hand of industry. On looking around the suburbs of the town nothing could be seen but hill and dale, and one could almost imagine when standing on one of these hills that the river twining so gracefully in the valley below was the clear stream it was even some forty years ago. If combined with this the hills be imagined, as they were, finely wooded, it was then evident what a beautiful neighbourhood it must have been before the days of steam. When one awakened from his imaginings and descended into the valley he found the once clear stream now like a river of ink, and was brought face to face with the awful results of river pollution. To Members of this Association especial interest would be taken in the present condition of the river, as no doubt it would be the duty of ourselves or successors to transform this river of ink into a comparatively pure stream once more. Only those intimately acquainted with the trade of a town like Dewsbury could fully appreciate the difficulties in the way of doing this, but on seeing the river, and considering the immense quantities of dyes, chemicals, &c., used annually in the district, then the magnitude of the question became apparent.

Being desirous of ascertaining approximately the quantities of chemicals and water used for manufacturing purposes, the author, in 1877, obtained the following particulars, viz. seven of the principal firms together used 2,859,000 gallons of water per diem

for manufacturing purposes, exclusive of water used for condensing purposes. Eight firms together used—

Nitric acid	15½	tons	annually.
Hydrochloric acid	3	"	"
Sulphuric acid	81	"	"
Nitro-muriatic acid	68	"	"
Ammonia	31	"	"
Soda ash	347	"	"
Bichlorate of potash	29½	"	"
Alum	55	"	"
Sulphate of iron	120	"	"
Sulphate of copper	18½	"	"

equal to a quantity of 2·44 tons of various chemicals per diem from eight firms. The author estimates that from 25 to 30 tons of the above chemicals are used daily in Dewsbury and neighbourhood; if to this be added about twelve to fifteen millions of gallons of water impregnated with spent dyes, &c., &c., and again add all the sewage contamination from an area of over 15,000 acres, it will show approximately the amount of pollution in the river Calder within a length of about two miles of its course.

The area of the borough is 1468 acres.

The first Local Board was formed in 1851, and the charter of incorporation was obtained in 1862. The population in 1801 was 4566; in 1831 it was 8272; in 1851 it was 14,502; and last census it was 24,773. It is now estimated at 32,000, so that in fifty years it has increased fourfold.

The sanitary condition of the town, as may be expected in a manufacturing town, is rather behindhand, but rapid strides have been made during the last few years. The chief sanitary evils may thus be enumerated:—

1. Beck floodings.
2. Back to back houses.
3. Common midden system.
4. The bad construction and non-ventilation of existing sewers and drains.
5. Direct communication between houses and drains.

Beck Flooding.

The Dewsbury Beck drains an area of 7000 acres, and receives the sewage and manufacturing refuse of Batley, Birstall, and parts of Dewsbury, Soothill Nether, Soothill Upper, and Gomersall. The ground on each side of the beck is very hilly, consequently in times of heavy rains the beck is very quickly greatly swollen. This beck passes through the town, the area of the covered

portion under the market place being 85 square feet, but on leaving the market place and passing down Long Causeway it is greatly contracted, the area being only 45 square feet. This of course is a serious obstruction to the discharging powers of the beck. Another obstruction occurs at its exit into the river, as the discharge is at right angles to the flow of the river. The consequence of these obstructions is that the covered portions of the beck are unable to pass the great quantity of water that comes down the open portions so quickly during a freshet, and so, on occasions, the water overflows into and through the streets and market place. Fortunately these occasions are not of frequent occurrence. The greatest evil arising from the beck is that at present all the sewers along the course of the beck discharge into it, and consequently in times of freshets all the basements in the low-lying portions of the town near to the beck are flooded. This latter will be remedied when the sewerage works are completed.

Back to back houses.

Whole rows of cottages may be seen in numbers within the borough so constructed that the back of one cottage is built to the back of another. The only space these houses have belonging to them is the street in front. The Members of this Association will see at once that want of ventilation in the house will nearly always be perceptible, and that such a system tends to increase the mortality in the borough.

The Common Midden System.

This system is, in the opinion of the author, the greatest sanitary evil that has to be contended with. There are about 2300 privies and 1500 ashpits in connection with them. These are for the most part not more than 4 to 5 yards away from a dwelling-house, and are really open cesspits. The excreta are deposited at one end of the ashpit, and ashes, garbage, &c., at the other end, consequently no ashes cover the excreta until the ashpit is at least half-full. There appears to be a great prejudice against the water-carriage system, but the author hopes that as soon as the sewerage works are completed, and the use of water-closets is extended, the prejudice will wear off, and that the middens will gradually be swept away. At present one privy is allowed to suffice for four houses.

The Sanitary Committee have seen the evils of the middens as

at present constructed, and instructed the author to lay before them a sketch showing an improved mode of construction. This the author has done, and all privies in future are to be so made.

The cost of the night soil department is about 1200*l.* per annum, equal to about 9*d.* per head of the population, or about 3*d.* in the pound on the rateable value of the borough.

The Bad Construction and Non-Ventilation of existing Sewers and Drains.

In 1878 the author opened up and examined all the public sewers within the borough. Nearly the whole of these sewers have been put in irrespective of any sanitary principles. The older sewers are generally square in section, and constructed of dry wallstones, with a rough stone cover on top; then followed a slight improvement, the walls being built in common lime mortar; after this came egg-shaped culverts, never less than 2 feet by 1 foot 6 inches, supposed to be constructed of 4½-inch brickwork in common lime mortar, but in the majority of cases the superintendence was so bad that very little lime was used and the bricks were put in dry. In all these sewers little or no means of ventilation or flushing were provided, consequently on inspection the author found a great number of sewers very much silted up and in some cases completely filled with sediment. Until the last five years no special ventilation was required to be put to private connections, but since then every house drain to new houses has to be ventilated by a special 3-inch pipe.

Direct Communication between Houses and Drains.

The greater portion of the houses within the borough are connected directly with the drains, a system which cannot be too strongly condemned; this is being gradually remedied, and no doubt when the sewerage works are completed all private connections will be examined, and where such a state of things is found, such direct communication will be cut off.

MORTALITY STATISTICS FOR THE BOROUGH FOR SEVEN YEARS, 1873–1879.

Total deaths per 1000	1873	equalled	23·0
" "	1874	"	32·9
" "	1875	"	26·6
" "	1876	"	22·4
" "	1877	"	21·2
" "	1878	"	27·4
" "	1879	"	23·1
Mean for seven years			25·2

In 1876 the author prepared a scheme of sewerage for the borough, which having been reported on by J. Bailey Denton, Esq., M. Inst. C.E., was with a few modifications finally adopted, and the author was instructed by the Council of the borough to prepare the necessary plans, &c.

The works comprise—

1. Outfall sewer.
2. Western main sewer.
3. Northern main sewer.
4. Internal sewers.
5. Surface water drains.
6. Pumping station.
7. Sewage farm.

Outfall Sewer.

The outfall sewer is 1605 yards in length, and is let in two contracts. Contract No. 1 includes 327 yards of 54-inch barrel sewer, together with manholes, shaft, and storm water overflow; 300 yards of this length are in tunnel, the depths varying from 18 to 90 feet. The depth of the centre shaft is 76 feet. This portion is constructed of 9-inch brickwork on a bed of concrete 6 inches thick and encircled with 6 inches of the same material.

The amounts of this contract are as follows, viz.:—

	£	s.	d.		£	s.	d.	
295 yards 54-inch brick barrel sewer, 9-inch work, in tunnel	1875	0	11	=	6	7	2	per yard lineal.
32 yards 54-inch brick barrel sewer, 4½-inch work, in open cutting, average depth 13 feet	95	16	7	=	2	19	11	„
1 manhole 16 feet deep	32	1	7					
1 shaft 76 feet deep	253	0	6					
Storm water overflow	167	9	8					
Contingencies	90	0	0					
Total	£2518	9	3					

The cost per yard lineal complete equals 10*l.* 13*s.*

The gradient of this sewer is 1 in 2000.

Contract No. 2 includes 1259 yards of 54-inch barrel sewer, constructed of 4½-inch brickwork encased in concrete 8 inches thick at top and bottom, and 10 inches thick at sides. Before the concrete is put over the brickwork a collar joint 1 inch thick of Portland cement mortar (1 to 1) is made.

The amounts of this contract were as follows, viz.:—

	£	s.	d.		£	s.	d.	
1259 yards 54-inch barrel sewer, 4½-inch work, average depth 12 feet 6 inches	5003	14	3	=	3	19	6	per yard lineal.
11 manholes	264	3	3	=	24	0	3	each.
Contingencies	390	7	0					
Total	£5658	4	6					

The cost per yard lineal complete equals 4*l.* 7*s.* 11*d.*
The gradient of this sewer is 1 in 2000.

Western Main Sewer.

This sewer will consist of as follows, viz.:—

193	yards	40-inch	cast-iron pipe	sewer,	gradient	1 in	1400.
233	"	36 "	"	"	"	"	700.
614	"	36 "	brick barrel	"	"	"	280 and 1 in 700.
324	"	30 "	"	"	"	"	280.
2350	"	27 "	"	"	"	"	104, 1 in 300, and 1 in 400.
487	"	18 "	fire-clay pipe	"	"	"	25·3 and 1 in 18·3.

The iron pipes will be laid just at the foot of the river bank, the invert of pipes being about 4 feet below the level of summer flow of river. All the pipes have turned and bored joints. The pipes will be laid on a bed of Portland cement concrete 8 inches thick, with a 4-inch bed of bituminous concrete over same, the pipes will then be covered with a 4-inch ring of bituminous concrete, and this will again be encased with a 7-inch ring of Portland cement concrete; the object of the bituminous concrete is to allow for the expansion and contraction of the iron pipes. The 36-inch, 30-inch, and 27-inch brick sewers will be constructed similarly to the outfall sewer Contract No. 2.

Northern Main Sewer.

This sewer will comprise as follows, viz.:—

640	yards	33-inch	brick barrel	sewer,	gradient	1 in	300.
28	"	33 "	cast-iron pipe	"	"	"	300.
757	"	30 "	brick barrel	"	"	"	180.
42	"	30 "	cast-iron pipe	"	"	"	180.

A portion of this sewer is let, comprising 640 yards of 33-inch brick barrel sewer, and 28 yards of 33-inch cast-iron pipe sewer, together with manholes and storm water overflow.

The amounts of this contract are as follow, viz.:—

	£	s.	d.		£	s.	d.	
640 yards 33-inch brick barrel sewer	1717	1	5	=	2	13	8	per lineal yard.
28 " 33 " cast-iron pipe sewer	172	15	6	=	6	3	5	" "
10 manholes	227	9	8	=	22	15	0	each.
Storm water overflow	206	3	10					
Contingencies	15	0	0					
Total	£2338	10	5					

The cost per yard complete equals 3*l*. 10*s*. 4*d*.

The construction of the northern main sewer will be similar to the sewers of 4½-inch brickwork, already described.

Internal Sewers.

These will comprise as follows, viz.:—

132	yards	24-inch	fire-clay pipe sewer.
1659	"	18 "	" "
3496	"	15 "	" "
7182	"	12 "	" "
7793	"	9 "	" "

Surface Water Drains.

These will comprise as follows, viz.:—

716	yards	18-inch	fire-clay pipe drains.
1,765	"	15 "	" "
7,753	"	12 "	" "
17,465	"	9 "	" "

Pumping Station.

This will be erected at the north end of the farm, the maximum quantity to be lifted is 1,500,000 gallons 100 feet high in 12 hours, the same engines to be capable of being attached to other pumps for lifting the sewage only 15 feet. These low-level pumps to be of as large a capacity as the engines will economically work. The engines will be in duplicate, provision being made for a future extension.

Sewage Farm.

The Corporation have purchased about 155 acres of land, part of which is in the township of Soothill Nether, and part in the township of Ossett. The price paid for 142 acres was about 106*l*. 10*s*. per acre; the remaining 13 acres costing 135*l*. per acre; the total cost being about 16,755*l*. About 60 acres of this land is tolerably level and of very fine soil, being mostly alluvial deposit; the remaining portion of the land is hilly, the highest point being nearly 100 feet above the lowest point. The land is

to be laid out on the principle of intermittent downward filtration combined with surface irrigation. The main drain is composed of 2-feet fireclay socket pipes laid at a depth of from 5 to 10 feet below the surface.

Near to the main outlet is constructed an inverted siphon underneath the Healey Mill Gort, composed of 3-feet cast-iron pipes with leaded joints and covered with Portland cement concrete. J. Bailey Denton, Esq., M. Inst. C.E., is the Engineer for laying out the farm, the author acting asResident Engineer. All the works on the farm are being carried out by day work.

Summary.

	Length. miles.	Estimated Cost. £
Outfall sewer	·91	8,300
Western main sewer	2·39	6,679
Northern main sewer	·83	4,538
Internal sewers	11·51	22,039
Surface water drains	15·74	8,000
Pumping station		8,000
Sewage farm and preparation		22,755
310 manholes		4,865
131 ventilators		917
Contingencies		5,000
Total estimated cost of works		£91,093

Total length of sewers and drains will be 31·38 miles.

General.

All cement used on the works is tested, the test specified being 250 lbs. to the square inch tensile strain. In all cases of brick sewers one-quarter of the circumference forming the invert is constructed of glazed fireclay bricks.

All concrete used is in the proportion of six of gravel to one of Portland cement.

All pipe sewers and drains have their joints caulked with tarred gaskin and a collar of Portland cement put round afterwards.

All mortar used is in the proportion of one of Portland cement to one of sand.

Accompanying this paper were a number of illustrations, which have been lithographed, and will be found at page 134.

DISCUSSION.

Mr. R. Vawser, in opening the discussion, wished to be informed what quantity of land it was proposed to employ at the farm, and what portion of the same would be laid out for filtration and irrigation respectively. He would next ask whether the quantity of sewage named included manufacturing refuse and rainfall, and if so, what quantity of each. He would also like to be informed as to the cost of laying out the land for filtration and irrigation purposes, and the cost per acre of levelling, draining, and sewage-carriers. The cost of the main sewer and tunnel from 18 feet to 90 feet below the surface is stated to have been but 6*l.* 7*s.* 2*d.* per lineal yard, which appeared a marvellously low price for such work.

Mr. J. Matthews Jones asked to be supplied with some details of the flushing arrangements, and wished to know whether the water was supplied by a company or by the Corporation.

Mr. T. Hewson said he had not been able to gather whether all the sewerage system discharged at a given point, and he would be glad to be informed what were the lifts of the pumps. He did not quite understand whether it was intended to have a separate system of sewers at Dewsbury—one for the sewage and one for the rainfall, or whether they were inclined that way and were merely utilizing their old sewers.

Mr. J. Allison observed that the covering over of becks and rivers running through a town in many cases subjected them to many serious inconveniences, and they ran the risk of damage from one thing or another. In an open stream they had always a chance of seeing whether there was any blocking or undermining going on. The inverts or the side walls might give way under flood, and by blocking the stream cause considerable damage. He thought this was a subject they might take up some day and discuss it fairly, to see whether or not it was a proper thing for them to do. He knew it was done in a large number of towns, but he questioned the propriety of it very much. Mr. Cross had promised to let them see a drawing of his privy and midden system, and had also touched upon the lime used for the old sewers. The old sewers were defective, and the lime was likewise defective. He thought that in many cases it would be prudent for corporations to find their own cement or mortar. There were also the 4 feet

6 inches culverts; he should like Mr. Cross to give them an idea of the difference in cost between 9-inch work and the manner in which he was carrying it out with 4½-inch brickwork and cement concrete, and his reasons for carrying it out in this particular way.

Mr. E. R. S. Escott remarked that he should like to be informed whether, where one closet was employed for four houses, the property was new or old. In most towns they required a closet to every new house. With respect to back to back houses, they only allowed eight to each block.

Mr. Vawser said he was glad that Mr. Escott had mentioned the question of small houses, and he hoped that that gentleman would read a paper on the subject at the forthcoming meeting at Leeds and ventilate the question thoroughly. He could not agree with Mr. Hewson that it was objectionable to have only one bedroom. People beginning in life had no occasion for more, and could extend their accommodation as their means and families increased. The question Mr. Allison had put as to the price of brickwork and concrete sewers would afford them an opportunity of gaining some valuable information.

Mr. Graham Smith said he should like to call their attention to the sluice valves in the Dewsbury works. Many sluice valves employed in sewerage works were lifted by means of an endless screw working in a thread placed on the back of the valve, and consequently these working parts were nearly always covered with sewage. Such was the case at the Merton works, and likewise in the valves mentioned by Mr. H. O. Smith in his paper on sluices and penstocks, read at the last Annual Meeting. In dock works, where sluicing was always carried on to a very great extent, it was customary to hang the valve or paddle by rods or chains, and have the lifting arrangements well out of the water. He was pleased to find that Mr. Cross had adopted this arrangement, as it was evidently a move in the right direction.

Mr. Cross, in replying to the discussion, said the farm comprised 155 acres, of which 142 acres cost about 106*l.* 10*s.*, and the remaining 13 acres 135*l.* per acre. He could not at present give much information about the area to be used for filtration. They expected to use about 60 acres themselves, but they anticipated that one or two if not more of the adjoining districts would join in their general scheme of sewerage. The cost of the tunnel was correctly stated at 6*l.* 7*s.* 2*d.*, but if the cost of shafts were included it would be increased to 10*l.* 13*s.* per yard forward. It

was intended to keep as much of the rainfall out of the sewers as possible. They were aiming at a separate system; if they found any of the old sewers which would answer their purposes they would use them, but where the sewers were constructed porous they would put in new drains by the side of the sewers, about 4 feet below the surface of the ground. He would take the opportunity of stating that the distance between the shafts was 146 yards. In sinking the summit shaft, on getting to a depth of 60 feet the works were stopped owing to the water. They then began driving at the south end of the tunnel, and although the distance between the shaft and the mouth of the tunnel was 150 yards, yet throughout the whole of this distance no bad air was perceptible, which he thought was owing to the porosity of the ground between the drift and the shaft. In flushing the sewers they took the water from the Corporation mains. Their pumps would have a high-level lift of 100 feet, and low-level lift of 15 feet; the reason for having a high-level lift and irrigation was that in winter the low lands would be liable to be very much flooded by back water from the river. The whole of the sewage would be discharged at the one outfall. In reply to Mr. Allison's remarks in reference to covering over the becks, he might say that he thoroughly agreed with all that gentleman had said, and he merely referred in his paper to what had been done already. As regarded the quantity of sewage, &c., he could only give the estimated quantities. Their calculation was 1,800,000 gallons for sewage proper, 200,000 gallons subsoil, and 2,000,000 gallons of trade refuse liquor; in time of ordinary rain the quantity would be 2,827,000 gallons per day, giving a total in twenty-four hours of 6,827,000 gallons; that would be their utmost. They would be able to raise over 9,000,000 gallons to the low level on the farm in twelve hours. They would have the separate system as far as feasible. In all the streets where there were no sewers at present they put in a sewer, and then cut out an offshoot in the trench as it was being filled up, and laid the surface-water drains about 4 feet from the surface of the road. The sewers were all jointed with gaskin and cement. The reason why they were using 4½-inch brickwork instead of 9-inch was that the ground they passed through was exceedingly good. The ground being very good throughout, they considered 10 inches of concrete would be the best thing to put in. As regarded the closets even new houses were allowed to have one closet for every four houses. Up to the present time there had been no limit made in the build-

ing of back to back houses. There had been no actual resolution passed to prevent any number of them being built in one row, but if the General Works Committee thought that the occupiers of any of the houses would have an inconvenient distance to go to the conveniences they made them alter their plans. In reply to Mr. Hewson's query with respect to the inverts of the sewers being kept on the same line, it was simply done in their case to gain fall. They had so little fall that they were obliged to keep the invert as near as they could in the same line. It was his intention to apply two screws to his sluice valve, one a quick screw and the other a slow one. One of the screws was connected about 6 or 8 inches above the bottom. He had just had a note put into his hands by one of the Members, who asked him if they had come to any arrangements with the millowners for the disposal of their refuse? There had been no arrangement made with the millowners. At present some turned into the Corporation sewers and no doubt they would continue to allow them to do so.

Mr. E. Pritchard observed that the paper had pointed out very clearly that the governing authority of Dewsbury had determined, in sanitary matters, not to be behind any other of the large towns in Yorkshire. There were one or two points he should like to have noticed, but in consequence of the limited time he would not now detain them. He could only say, from what he had seen that day, that he had been very much pleased with the paper and the works. Instead of 4½-inch rings he should like to have seen 9-inch rings, but Mr. Cross had told them that the ground was very good and firm. There was also a point referred to in water-closets. Mr. Cross said there was a great prejudice against them being used. Unfortunately in almost every case there had been the same prejudice when they wished to remove the old cesspool. The public had been more accustomed to them all along. He took it, that the prejudice would be considerably modified when the more scientific way of disposal by the construction of water-closets came into use. The disposal of the sewage by intermittent filtration appeared to be a good system; but it was one they could not determine for universal adoption, as one system of sewage disposal would not do for every town. There appeared to be at Dewsbury a considerable area of land which was well adapted for doing the whole work in a satisfactory manner, and he had no doubt but the works would prove a successful undertaking for the purification of the sewage.

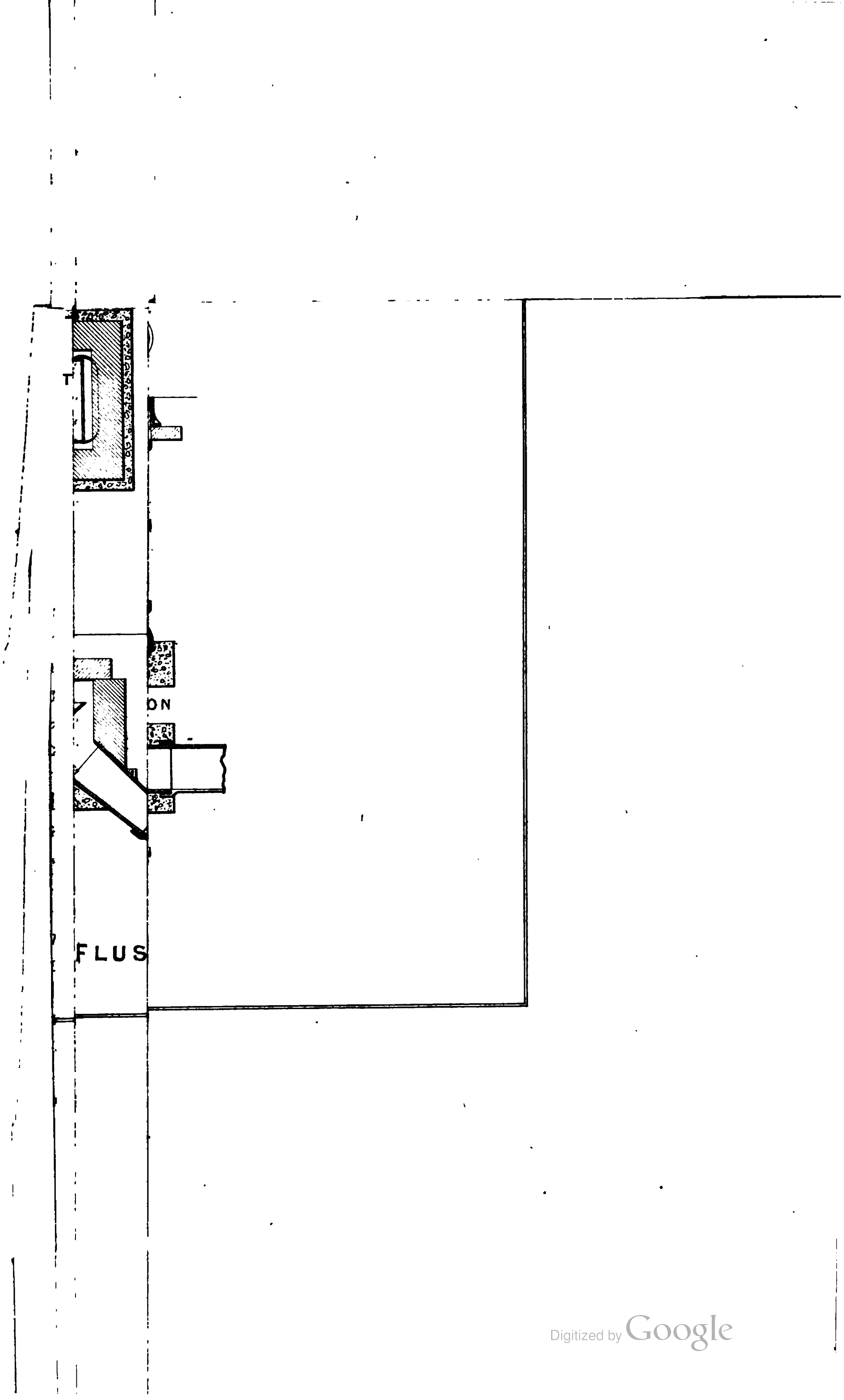
By the courtesy of the Leeds Tramway Company and Mr. Trusswell, the Members were taken a trip in a tramcar drawn by a steam tram engine, made by Messrs. Merryweather and Sons.

Mr. Escott said he thought they ought to propose a vote of thanks to the Tramway Company and its manager. He had therefore great pleasure in moving a vote of thanks. They had enjoyed their trip and were very much obliged to the Tramway Company.

Mr. B. C. Cross said he had great pleasure in seconding the motion. When he first mentioned the matter to Mr. Trusswell, that gentleman took it up heartily and warmly, and he was sure they would all agree with him when he said that Mr. Trusswell had carried out his promise and given the members great satisfaction.

Mr. Pritchard said that before he put the resolution he wished to say that personally he had a great deal to thank Mr. Trusswell and the Tramway Company for, not only for the convenience of having a ride in the tramcar drawn by steam power as a motor, but also the interest and instruction it had afforded him. He was sure they were deeply obliged to Mr. Trusswell. So far as he had seen everything tended to the successful introduction of steam instead of horse power. He considered that the engine reflected the greatest credit upon its makers. He had been agreeably surprised with the result, for although he had always been in favour of steam as a motor for tramways, he had had some feelings of alarm as to the effect it would have upon horses; but judging from what he had seen that day, and he had carefully noted all kinds of horses which had been met, some young spirited horses, others perhaps not so spirited—for after having travelled over 3½ miles of road he had a very good opportunity of seeing what would be the effect—and he was of opinion that, excepting a little nervousness shown, the horses went quietly along. He hoped the gentlemen present would use their interests for introducing steam as a motor. In conclusion he desired to thank Mr. Trusswell and the Tramway Company for the opportunity they had afforded them of ascertaining the merits of steam traction.

Mr. Trusswell acknowledged the vote of thanks in a few appropriate remarks.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ANNUAL MEETING AT LEEDS,

May 27, 28, and 29, 1880.

ADDRESS OF THE PRESIDENT,

A. W. MORANT, M. Inst. C.E., Borough Engineer, Leeds.

Gentlemen,—I thank you sincerely for the honour you have conferred upon me by electing me your President for the ensuing year.

It is satisfactory to know that our Association is steadily progressing, and that the chief object for which it was formed, viz. the meeting together of its members, the interchange of ideas, and the examination of various works which we have under our charge, is found to be beneficial in every respect.

Iu the offices we fill we have much to contend with; the large number of masters whom we have to serve, comprising naturally men of all kinds of temperaments and ideas, and the changes annually taking place amongst them, by which we frequently lose those who best understand what requires to be done, make it very difficult to carry on our work, do what we will, without fault-finding from some. Let us, however, by strictly honourable conduct, at any rate endeavour to command their esteem, and at the same time, by care and attention, make as few mistakes as possible. We being human are all liable to err, but one of our members publicly stated to a number of persons in my presence that *he* had never made a mistake in his life. If his assertion was correct, all that can be said is that he is a lucky fellow, and I wish there were many more equally fortunate. It is certainly satisfactory to know that we number at least one perfect man amongst us.

During the past year there has not been any Act of Parliament passed affecting such matters as we are interested in, no new method for the purification of sewage has been introduced, and when it is proposed to dispose of it by irrigation, the system so strongly recommended by the various Royal Commissions, the difficulty and expense of obtaining land continues rather to increase than to diminish, for instance, take the case of the recent inquiry at Hampton Court respecting the disposal of the Thames Valley

sewage just concluded, but the result of which is not yet known.* Here the cost of the inquiry alone is said to be nearly 30,000*l*.

There seems to be good reason that a Town Council should be able to obtain the land required for sewage irrigation at its agricultural value, for the owners of land all round the town, and for some distance from it, derive a commercial benefit from the mere presence of the population, inasmuch as proximity to a town enhances the value of the land, without the owners, in most cases, contributing in any way to its increased value.

The means at this time in use for the purification of sewage appear to be chiefly limited to broad irrigation, as at Aldershot, Bedford, Blackburn, Cheltenham, Croydon, Doncaster, Leamington, Merthyr, Warwick, &c.

Intermittent downward filtration on land.

Treatment in tanks by lime only, as at Birmingham, Leeds, Leicester.

Lime, with subsequent filtration through coke, as at Bradford.

The Coventry process, as at Coventry, where lime and sulphate of alumina are used.

The A. B. C. process, as used at Aylesbury.

Hille's process of adding lime, tar and magnesium, as at Windsor.

When land can be obtained, irrigation is doubtless the most satisfactory and cheapest method of disposing of the sewage, and it is very desirable that a portion should be reserved for land filtration, so that upon it can be turned so much of the sewage which has to be dealt with daily as the crops upon the remainder of the land are not in a condition to receive with benefit.

Street paving presents nothing particularly new, except that at Middlesborough paving blocks have been manufactured from furnace slag, and some which have been laid down appear to stand the traffic well. The joints are close, and the blocks make a neat pavement. In Whitehall Road, in this town, ten lengths of the following descriptions of paving of various sizes have been laid, in order to test their durability, viz. whinstone from Great Ayton, Middleton Teesdale, and Longhoughton, stone from Threlkeld, near Keswick, from Graiglwyd and Penmaenmawr, and the slag-blocks, 3½ inches by 6 inches, of the Tees Scoria Block Company, at Middlesborough.

* The Local Government Board in this case again refused to sanction the scheme for the disposal of the sewage by irrigation, but extended for three years the time allowed for the diversion of the sewage from the Thames.

The use of Portland cement concrete for footways is gaining ground. If well done it appears very durable, is very clean, and even in this neighbourhood, within a short distance of the principal flagstone quarries, it can be laid rather cheaper than 3-inch flags. The plan adopted is to dig out the ground, and lay a foundation of broken stone and bricks about 6 inches thick, well rammed; upon this the cement concrete mixed in the proportion of one of cement to three of finely broken granite is laid to an average thickness of about 2 inches worked into the foundation, and then floated and trowelled to a smooth surface. The cost complete is about 4*s.* 6*d.* per yard super.

Street lighting by electricity, which a few months ago seemed likely to a great extent to supersede the use of gas, has not been adopted so speedily. One of the most successful instances of the application of the electric light appears to have been made at Blackpool by the Corporation during last autumn, where 1000 yards in length of the promenade and the area of sea between the two piers was perfectly illuminated. There were upon the promenade four lights 350 yards apart, and one upon each pier at about 400 yards from the shore; each light was placed in a plain glass lantern 60 feet above the level of the roadway.

The machines and lamps were those of Siemens, and the total outlay, including two portable engines of 16 horse-power each, 8800 yards of cable, engine and machine house, &c., was 2800*l.*, whilst the working expenses, including interest, were per night of 5½ hours 3*l.* 6*s.* 10*d.*, being at the rate of about 2*s.* per hour per lamp of 6000 candle-power.

As I am not aware of any other matters to which it is necessary to call your attention, it may be interesting to you if I give a short description of the various departments of the Corporation of Leeds, which have to do with engineering and sanitary affairs, and I will therefore proceed at once to do so.

The Borough of Leeds comprises an area of nearly 22,000 acres, and is divided into eleven townships, and contains parts of two hamlets adjoining.

The River Aire flows through the district from north-west to south-east, and the natural drainage of the land is carried into the river by Sheepsear and Gipton Becks on the north side, and by the Farnley, Benyon and Hol Becks on the south side.

The population is now estimated by the Registrar-General to be about 320,000, and the rateable value is 1,096,020*l.*

The district lies upon the lower coal measures and the millstone grit, and varies much in levels, the river where it leaves the borough being 70 feet, and the highest land, which is on the northern boundary, being 530 feet above ordnance datum, respectively.

The becks above mentioned, as they flowed through the town, being in their course much polluted by various manufactories, and also by house drainage and filth, and the beds being rough, uneven, and full of nearly stagnant pools (small dams having been formed by millowners) much nuisance arose; the Corporation consequently procured an Act of Parliament in 1866, and at a cost of about 39,000*l.* built side walls and paved the bottoms with stone, with a centre channel of semicircular shape sufficient to conduct all the water passing in dry weather, and side-slopes over which it flows in floods, the house drainage and other nuisances fouling the streams were diverted, and though costly, the work has proved to be a great sanitary improvement. There are now no pools, and the water is always rapidly flowing away. A length of about three miles was thus improved.

Leeds is well sewered with the exception of parts of the outlying districts, which are being rapidly completed. During last year 17 miles of sewers of various sizes were constructed, and the total length of sewers within the borough is now about 187 miles. Up to the end of August, 1879, the total amount spent in sewerage and in the outfall works at Knostrop has been 436,000*l.*

The railways, river, and canals have to be crossed several times, sometimes by iron tubes in line with the sewers, and sometimes depressed as inverted siphons. In connection with these I may mention that it occurred to me to make a trial of Priestman's self-acting bucket for the purpose of clearing the deposit from the settling tanks, which in some cases are about 30 feet in depth, and nearly 20 feet in water. The bucket consists of two quadrant-shaped vessels hinged together at the upper edge, it is lowered open, fills itself in the act of closing, and holds the mud securely whilst it is being drawn up through the water. It answers its purpose very well, and obviates the necessity of pumping out the water from the tanks, and sending men down.

By the courtesy of Messrs. Priestman, of Hull, I am enabled to exhibit a model and some photographs showing the mode of action of this bucket.

The principal main sewers are constructed of brickwork, but as Leeds is in the heart of the sanitary tube manufactories it has always been the practice to use fireclay tubes when practicable, the

largest sizes being 30 inches in diameter circular, and 30 inches by 21 inches egg-shaped.

You will have an opportunity of seeing the manufacture at the works of Messrs. Ingham's and of the Farnley Company to-morrow afternoon.

All the sewers are freely ventilated by means of open gratings, or by the gullies which are constructed to act as ventilators. This system has now been in use for nearly seven years and is found quite satisfactory. At present we have about 20,000 gullies acting as ventilators. It is of course the very large number of openings which prevents any nuisance from the escaping gases. In sewering new districts the old drains and watercourses are when possible reserved for the purpose of carrying away the surface drainage. The size of the main sewer at its outfall is 8 feet by 7 feet 9 inches. The sewer terminates at the sewage works at Knostrop about two miles and a quarter from the Town Hall. The site of these works is rather low, and in times of flood in the river the water backs up and causes much inconvenience. Negotiations are now in hand with the Aire and Calder Navigation Company for the removal of a dam across the river one mile and three-quarters below the works, by which an additional fall of about four feet will be obtained and the effluent have a much freer discharge. It will not be necessary to detain you here with any account of the outfall works as you have a full description of them in the third volume of the 'Proceedings' of this Association in a Paper which I read at the Annual Meeting in London in July, 1876.

It may however be stated that at the present time the sewage of about 287,000 of the inhabitants of the borough reaches the works. From recent carefully taken gaugings the average daily quantity in dry weather is found to be about 10 millions of gallons. Lime burnt from carboniferous limestone, and which is obtained from Skipton, is at present alone used for the clarification of the sewage and is found to produce an effluent sufficiently good to satisfy the requirements of the injunction obtained in 1870. I may mention that about 1 ton of lime is used to every million of gallons. The total expenditure at these works during last year, including pumping the sewage, was 5848*l.* The sludge is of course here, as everywhere else, the great trouble. Extensive drying apparatus was erected, but hitherto no remunerative return has been obtained, so that of late it has not been used. We have however a large area of spare ground and can go on for some time.

All this you will see for yourselves on Saturday when you visit

the works. Our old member, Mr. Monson, has lately patented a plan for getting rid of some of the sludge by mixing it with from a half to two-thirds of brick earth, and upon the table are some of the bricks made by him and consisting of a portion of our sludge; in quality they are satisfactory, but it remains to be seen if they can compete in price with ordinary bricks. I fear that for success the sewage works should adjoin the spot whence the necessary clay can be obtained.

The Sanitary Department consists of the Medical Officer of Health, Borough Analyst, a Superintendent and Chief Inspector of Nuisances; three Clerks; ten Sub-Inspectors of Nuisances; four Disinfecting Men, whose duty is to disinfect all clothing, bedding, &c., and fumigate infected houses (they have two horses and vans for removing the bedding, &c., to and from the disinfecting apparatus); two Meat Inspectors; one Dairy and Cow Shed Inspector; one Inspector of Lodging Houses and Canal Boats.

There is a Public Mortuary containing morgue, dissecting room, two rooms for receiving the dead bodies of persons brought from crowded dwellings and awaiting burial, or who have died of infectious diseases, inquest room, &c.

The cleansing of the town is performed by a staff of about a hundred scavengers employed by the Corporation aided by thirty-two horses and carts; they sweep the paved streets and markets and empty the gullies, the macadamized roads being cleansed by the Highways Department.

For watering the streets twenty-eight water-barrels and carts are employed, and with the cost of the water used, an expenditure of about 1750*l.* a year is incurred.

The Night-soil Department is, as everywhere, a source of heavy expense, the contract for emptying bins and removing the night-soil and refuse being at the rate of about 12,333*l.* per annum. There are in the borough about 40,000 privies, 15,000 dry-ash pits, 3000 box-closets, 12,000 ordinary water-closets, and also 1720 trough water-closets which are used by 4945 tenants.

These trough closets are a great improvement upon the old common privy; they should be attended to, if possible, daily. In Leeds sixteen men are employed to cleanse them and refill the troughs with water. Our District Secretary, Mr. B. C. Cross, of Dewsbury, has taken out a patent for an improved method of emptying the trough by means of a siphon with a self-acting arrangement; this will obviate the necessity for such frequent attention.

Many of you will have experienced the great difficulty of finding suitable tips within a reasonable distance where refuse could be deposited without causing a nuisance, and for some time Leeds has suffered in this respect. The introduction of Fryer's patent Destructor has however removed the difficulty, and we are now enabled to dispose of all refuse without nuisance and to considerably reduce the distance and consequently the cost of cartage. For the purpose of trying the system, a yard, with one six-celled destructor and a carbonizer, was first established near the workhouse at Burmantofts, about two miles from the Town Hall in a north-easterly direction, and the result was so satisfactory that last year another was erected in Armley Road about one mile in a westwardly direction and it also is doing good work.

As the subject is a very important one, and no doubt will interest you, I will shortly describe the arrangement and construction of the apparatus.

The destructor consists of six compartments or cells formed of brickwork lined with firebricks and tied with iron rods, it occupies a space of 22 feet by 24 feet and 12 feet in height, and is so arranged that there is an inclined road leading to a platform over the top of it on to which the refuse is carted, and there is also another incline from the level of the firing floor to the adjoining road by means of which the mortar, charcoal, old iron, &c., is carted away. At Armley Road this low road also leads to a tip at the canal side where manure is barged away.

Each of the six cells is capable of destroying seven tons of refuse in twenty-four hours, and consists of a sloping furnace with hearth and fire-grate covered in by a reverberatory arch of firebrick with one opening for the admission of the refuse, another for the gases to escape into the flue, and a furnace frame and doors for the withdrawal of the clinkers.

The refuse, which is shovelled from the platform into the cell, falls upon the incline and slides forward on to the sloping hearth whence, when sufficiently dry, it is helped forward on to the fire bars, where it burns somewhat fiercely, the firebrick arch above concentrating the radiant heat upon it. The opening for the entry of refuse is divided from the opening for exit of gases by a wall, a bridge preventing the refuse, which is heaped up immediately below, from finding its way into the flue also.

At intervals of about two hours the clinkers are withdrawn through the furnace doors and a further charge of refuse shovelled in at the top. The result of the process is that everything is con-

sumed or converted either into clinker or a fine ash. Every two cells are also provided with an opening for the introduction of infected mattresses, diseased meat, &c., on to the fire, where everything is readily consumed without causing smell.

The gases from the furnaces on the way to the chimney shaft pass through a multitubular boiler 6 feet in diameter and 10 feet in length, and make steam to drive a horizontal engine with cylinder 12 inches diameter and 2 feet stroke, which works two mortar mills with pans 8 feet in diameter. In these the clinkers made in the destructor are mixed with lime and ground into an exceedingly strong mortar which is readily sold at 5*s*. per load.

No fuel of any kind is required the ashes mixed with the refuse being amply sufficient. The old tins and iron after passing through the fire are sorted out and sold for old metal.

During the year 1879 the following quantities of materials were consumed in the destructor:—14,000 tons of rubbish, 59 beds, 131 mattresses, 264 carcases of pigs which had suffered from swine fever, 1 cow, 8 sheep, 2 lambs, 28 quarters of bad meat, 13 cwt. of bad meat.

Since the Burmantofts destructor was started two years and a half ago 30,041 tons of refuse have been consumed by it. (This is taken to the 31st April last.)

For each depôt the following men are required:—1 fireman, who also acts as engine driver; 4 furnacemen; 1 labourer, who attends to two mortar mills—and the same for night duty.

The carbonizer is used to convert the refuse obtained from the sweepings of the paved streets and the markets and other vegetable refuse into a carbon, very useful as a manure and deodorizer, and which finds a sale at 30*s*. per ton. The carbonizer consists of a group of eight brickwork cells and furnaces, each cell having its own distinct furnace alongside of it. It is 26 feet long by 12 feet wide and 15 feet 6 inches high, tied together with iron rods and angle irons.

The refuse to be carbonized is fed into the apparatus at the top, the loose cover of the cell being removed for that purpose and immediately replaced. Within the brickwork cells are hung by means of cast-iron plates, fixed in its walls, a series of cast-iron plates or eaves, touching the walls along the top edges, but standing free from the walls some inches along their lower edges. These plates are arranged to overlap one another and form a continuous sloping ledge or eave, winding round and round the cell in a kind of spiral.

Near the bottom of the cell the spiral eave finishes with a fire-block eave, the lower edge of which rests on a wall dividing the contents of the cell on one side from the hot gases of the fire, which are admitted to it on the other side.

The refuse is fed into the cell until it forms a solid mass within the wall of the spiral eave, being withdrawn at the bottom as it gets sufficiently charred, but it is not mobile enough in its nature to rise up again either underneath or behind the eaves, so that a space is there left forming a continuous flue, in connection with the chamber behind the fire-block at the bottom of the cell, and up this flue pass the hot gases from the fire, thus heating the contents of the cell. At the top of the cell these gases pass through the damper frame into the vertical flue, and so into the main flue and thence to the chimney.

The process undergone by the refuse is as follows, after being thrown in at the top of the cell it sinks gradually as it becomes closer packed and as the finished charcoal is withdrawn at the bottom, and as it sinks it continually comes in contact with hotter and still hotter plates until at the bottom of the cell it enters a chamber of nearly red-hot firebrick.

No air is admitted during the process except a slight amount which reaches it from the flue behind the eaves, so that instead of being consumed it is charred. The cell terminates about 2 feet from the ground in a strong cast-iron plate, in which is an opening closed on the under side by a sliding door; this is open at certain intervals of about three hours for letting out a charge of charcoal into a small truck which is run in below the plate ready to receive it. The furnace, with fire-grate and door, is of ordinary construction, and within it a thick dull fire is kept up. Sight or peep-boxes are provided to enable the flues nearest the fire to be cleansed, and similar peep-boxes higher up allow a view on to the backs of certain of the cast-iron plates for the purpose of seeing that they do not become overheated.

Though the cast-iron plates are bolted to the walls, or through the walls to one another, they are removable if need be without pulling down any of the brickwork.

The charcoal, which comes out of the carbonizer red hot, is cooled in a char-cooler by passing through a revolving cylinder over which cold water is continually streaming, and it is sifted as it issues from the outer end. This cooler is also driven by the steam engine which works the mortar pans.

Each cell deals with about fifty hundredweight of refuse in every twenty-four hours, and the fuel required for the furnaces is sifted from the contents of the dry-ash pits, it not being necessary to purchase any.

The cost of an establishment with one six-celled destructor, a carbonizer with eight cells, steam engine, boiler, mortar mills, weigh-house, chimney-shaft, &c., complete, is about 4500*l.*

No nuisance of any kind is experienced in the vicinity of the depôts, and this system of dealing with the refuse of towns appears to be gaining ground. The apparatus has been adopted in Kralingen, near Rotterdam, Leeds, Heckmondwike, Blackburn, Bradford, Warrington, and Derby, and is I hear about to be adopted in Bolton, Dewsbury, and Rotherham.

The total cost of the sanitary department in the year ending 31st August, 1879, was 34,125*l.*

As a matter of caution, I may mention that a few years ago the Sanitary Committee ordered all ash pits to be connected with the sewers, and the result was that the scavengers removed the gratings, and forced the ashes down the drains, the effect being the stopping of the pipe sewers in several streets. The practice is now discontinued. It never was necessary, as all ash pits are obliged to be covered, and slops should be thrown down the gullies in the yards or streets.

We have stringent building bye-laws, which are rigorously enforced under the direction of a building inspector, four sub-inspectors, and two clerks. The inspectors examine all foundations, see all sewer connections and drains before they are covered up, and that the buildings are in every respect carried out in accordance with the drawings passed and stamped by the Building Clauses Committee, and of which tracings are deposited, and no dwelling-house can be occupied until the inspector has certified that all is correct. About seventy sets of plans are disposed of at each fortnightly meeting.

The length of paved streets within the borough is 107 miles, and of macadamized roads 132 miles, making a total of 239 miles.

The principal streets, and those which are subject to heavy traffic, are paved with granite or whinstone setts, and those where the traffic is slight with stone from the neighbourhood of Bradford. The natural foundation is generally sufficient, but if the streets have been made over broken ground and the site of old buildings, concrete is used. The joints of the paving-stones are always filled with a mixture of pitch and tar, and I would call your attention to a small matter of detail practised here and in many northern towns,

which might I think be advantageously followed elsewhere, particularly in London; it is that the causeways and crossings are made to meet, so that passengers have not to step down off the kerb to a level of 6 inches or so below. This plan makes crossings much less inconvenient.

The whole of the stone for the repair of the macadamized roads is brought from the Corporation Quarries at Great Ayton, nine miles from Middlesborough, and sixty-eight miles from Leeds, and in addition, about 4000 tons of dross are used in the neighbourhood of the furnaces. The stone is quarried from a whinstone dyke, about 70 feet in breadth, enclosed in shales of the lias formation. Last year 11,823 tons of rough stone, 13,561 tons of machine-broken, 1479 tons of hand-broken stone, and 1245 tons of paving setts were brought into the town from the quarry for use, in all 28,108 tons, and during the same period 3500 tons of whinstone setts, 1460 tons of granite setts, 1840 tons of Bradford paving stones, 2815 super yards of setts, 7000 yards of flagstone, and 1328 lineal yards of kerbstone were purchased.

The granite used is from Mount Sorrel and Dalbeattie, and stone from Penmaenmawr is also occasionally laid. In the borough 240 men are employed upon the roads in repairing and cleansing, and twenty horses and carts, besides those loading stone, which are paid by contract.

The labour for new paving and repaving is done by contract, the price being about 9*d.* per yard, including carting, and ashes for the bed.

We have two of Aveling and Porter's 15 ton steam road rollers for consolidating the broken stone used in repairing the macadamized roads, and a portion of the road scrapings is reserved and used for the purpose of blinding the stone. Their use is found to be most advantageous.

The following are the ordinary costs of laying various pavements, exclusive of expense of concrete foundations:—

				s.	*d.*	
Granite setts, 3 inches to 3½ inches thick,	5	inches deep		9	9	per yard super.
" "	6	"		10	6	"
" "	7	"		12	6	"
Whinstone "	5	"		7	0	"
" "	6	"		8	0	"
" "	7	"		9	0	"
Bingley setts, 12 inches to 18 inches long, 6 inches thick, 9 inches deep				8	0	"
" 6-inch cubes				4	6	"
" Shipley, or Bolton wood				4	3	"
Boasted Bradford kerb, 12 inches by 8 inches				4	0	per lineal yard.
3-inch flagging, self-faced				5	3	per yard super.

The concrete foundation of blue lias lime concrete 9 inches in thickness, including digging, 3*s.* 6*d.* per yard super. There are a few streets paved with wood, originally laid down by the Improved Wood Paving Company, upon a foundation composed of two layers of inch boards, one laid transversely and the other longitudinally, but the plan did not answer, and the blocks are now laid upon a foundation of concrete—the price is at present about 12*s.* per yard. There is not any asphalte paving in Leeds. The cost of the highways department for the year ending 31st August, 1879, was 51,400*l.*

The streets and roads are lighted by about 7000 lamps at a cost of about 2*l.* 7*s.* per lamp per annum. Each burns about 3½ cubic feet of gas per hour.

Leeds possesses an abundant supply of good, wholesome water, the present consumption being at the rate of about seven millions of gallons per day, of which nearly two millions are supplied for trade, and the remaining five millions consumed for domestic purposes. The works belong to the Corporation. The first portion of the works was carried out by Mr. J. W. Leather, but the reservoirs in the Washburn Valley were constructed by Mr. Thomas Hawksley, under the direction of Mr. Edward Filliter, who has designed and is now carrying out the enlargement of the Eccup Reservoir. The whole of the works are of the most substantial nature, and no expense has been spared to make them efficient and durable in every way.

The source from whence the water is procured is the River Washburn, a tributary of the Wharfe, and the point where the water is first impounded is about fifteen miles from the Town Hall, measured in a straight line.

In the valley are three large reservoirs for the storage of water for town use and compensation for the mills. The drainage area from which these reservoirs are fed is about 22,000 acres, and the average rainfall is here about 36 inches per annum. The most distant reservoir, known as Fewston Reservoir, has an area of water surface of 156 acres, and a capacity of 866 millions of gallons, the greatest height of bank is 68 feet, the inner slope is 3½ to 1, and the outer 4 to 1, with a benching 50 feet wide, with slopes 3 to 1. The water is passed through the bank by means of a culvert, 11 feet in diameter. The puddle trench varies from 20 to 70 feet in depth, and is 24 feet in breadth. The waste weir is 170 feet in width, and the bye-wash is 100 feet in width at the top, tapering to 75 feet.

Swinsty Reservoir, the next below, has also 156 acres of water surface, but a capacity of 961 millions of gallons. The greatest height of bank is 67 feet, and the water is drawn off by means of two lines of 30-inch pipes, laid in a tunnel, 12 feet in diameter, and 526 yards in length, driven in the solid rock round the east end of the embankment. At about the centre of the tunnel is the valve shaft, which is 80 feet in depth. The embankment is 500 yards in length, 24 feet in width at the top, with inner slopes 3 to 1, and outer 2½ to 1, with a benching 50 feet in width. The puddle trench varies from 20 to 60 feet in depth, and the puddle is 8 feet wide at the top, and 24 feet at the bottom. The waste weir is 165 feet in width, and the bye-wash 100 feet, tapering to 75 feet.

The third on the line of the valley is Lindley Wood Reservoir. It has a water surface of 117 acres, and a capacity of 749 millions of gallons. The greatest height of bank is 67 feet, and the water is drawn off by means of two culverts through the embankment, each 10 feet in diameter, with valve towers and double valves.

Very great difficulties were experienced and expense incurred at this reservoir, the puddle trench having to be excavated on the Farnley side of the embankment to a depth of 160 feet. A large landslip also occurred just below the north-east end of the embankment and alongside the bye-wash, and many thousand cubic yards of shale had to be removed. It was utilized by being added to the back of the outer slope. The embankment is about 360 yards in length, and in consequence of the addition above mentioned has a width of 55 feet at the top, the inner slope 3 to 1, and the outer slope 2½ to 1. The puddle trench is 8 feet in width at the top, and 24 feet at the bottom. The waste weir is 160 feet in width, and the bye-wash 100 feet, tapering to 75 feet, and 880 feet in length. The excavation for this bye-wash was very heavy, the cutting being 35 feet in depth.

Swinsty Reservoir is about 450 feet above sea-level, and the water is conducted from it by two lines of 30-inch pipes, each about twelve miles in length, to the last storage reservoir at Eccup. At present this has only an area of 45 acres, and a capacity of 250 millions of gallons, but an embankment is now being constructed 200 yards in length and 80 feet greatest height, which will increase the area to 195 acres, and the contents to 1485 millions of gallons, so that the total capacity of the four reservoirs will be 4061 millions of gallons. One great advantage which will ensue from the enlargement of this reservoir will be that in case of accident to the works

in the Washburn Valley there would be close to the town a supply of water equal to between six and seven months' consumption, supposing that not a drop of water entered the reservoir from the Washburn. A further advantage consists in the greater time in which the water will have to become clear before being sent on to the filter beds. It is worthy of remark that Eccup Reservoir alone, when enlarged, will be of greater capacity than the whole of the subsiding, storage, and service reservoirs now in use for the supply of water to London.

The filter beds, seven in number, are situated at Weetwood, about three miles from Eccup Reservoir, and the water is conveyed to them in a conduit, partly in tunnel under Black Moor and partly by 40-inch pipes. The surface of water in the beds is 325 feet above the sea, they have a sand area of five acres, and are constructed in the ordinary way, the filtering materials being gravel and sand.

Here the whole of the water supplied to the town is filtered. The greater quantity gravitates to the town, and is distributed through three main pipes, one 30 inches in diameter and two each of 18 inches diameter, and the remainder flows to the well of the pumping station at Headingley, from whence it is pumped to the high-service reservoir at Moortown and Bramley.

There are also service reservoirs at Woodhouse Moor, Beeston, and Wortley, but these are filled by gravitation from Weetwood.

The reservoirs are also covered, and the water kept in a pure and cool condition.

The pumping station at Headingley consists of two rotary condensing engines, one of 30 horse-power and the other 15 horse-power, and two others recently erected each of 30 horse-power. There are four boilers. About 700,000 gallons are here pumped to the high levels in every twenty-four hours.

At the junction of the Washburn with the Wharfe there is a gauge, where the four millions of gallons of water which have, by Act of Parliament, to be passed into the Wharfe for compensation to the millowners, are measured, and six millions of gallons are also measured and sent forward by a 27-inch main to the pumping station at Arthington. This is situated upon the side of the river Wharfe, from which river the Corporation have power to take six millions of gallons per day, and for five years pumped this quantity into the Eccup Reservoir, the lift being 260 feet.

Here there are nine boilers, a fine Cornish engine of 300 horse-

power, with cylinder 90 inches diameter and 11 feet stroke, and pump 30 inches diameter and also 11 feet stroke.

There are also a pair of combined high and low-pressure engines of 100 horse-power, each working bucket and plunger pumps 24 inches diameter with 4 feet stroke.

These works are now kept in case of any accident occurring to the works in the Washburn Valley, but at some future time, if the population largely increases, will be required to supplement the supply afforded by the gravitation scheme.

The total cost of the waterworks up to the end of the last financial year has been 1,343,634*l.*, but in spite of this the Corporation is able to give a constant supply of water at very moderate rates; for instance, a house the rental of which does not exceed 20*l.* per annum is charged at the rate of 1*s.* in the pound, and one not exceeding 50*l.*, 2*l.* per annum.

Water-closets are charged extra at the rate of 5*s.* 4*d.* for the first and 2*s.* 8*d.* for each additional closet, but in cottages of 10*l.* rent and under only 2*s.* 8*d.* is charged for the closet.

Baths are allowed free.

Water is supplied for trade purposes by meter at the rate of 6*d.* per thousand gallons. The meters used are those of Siemens and Adamson.

Mr. Hawkesley has in speaking of the price remarked that, so charged, water is by far the cheapest commodity supplied to us, it being collected, brought fifteen miles, filtered, and delivered into our houses for three-halfpence a ton. At the end of August last 72,026 houses were supplied, and 11,522 water-closets.

The gas undertaking of the Leeds Corporation was purchased from two competing companies in 1870. The price paid was 40 per cent. premium upon the stock and share capital of the companies, the total cost to the Corporation being in round figures 800,000*l.* Since the transfer there has been a further expenditure of about 150,000*l.*, the capital expenditure at the present time being 950,000*l.* In 1870 the gas manufactured was 850 millions of cubic feet, and the sale 650 millions, the loss (including gas consumed upon the works) being 200 millions per annum. In the year ending June 1879, the gas made amounted to 1250 millions, and the sale to 1063 millions, the loss including use on premises being 187 millions. The prices charged for gas have been as under: 1870 to 1874, 3*s.* 6*d.*; 1875 and 1876, 3*s.* 9*d.*; 1877, 3*s.* 3*d.*; 1878, 2*s.* 9*d.*; 1879, 2*s.* 6*d.*; 1880, 2*s.* 2*d.*, with a

discount of 2½ per cent. if paid for within one month of demand.

The quality of the gas supplied, when tested by the London Standard Burner, is equal to an average of 18½ candles. The length of mains is upwards of 500 miles, the area of lighting covering 35 square miles, the number of meters fixed is 68,777, of which about 85 per cent. are 2-lights and 3-lights. The manufactories are three, as under: Meadow Lane, containing 792 retorts; New Wortley, containing 380 retorts; and York Street, containing 380 retorts; total, 1552. The works at York Street have been almost entirely rebuilt during the last two years under the direction of Mr. H. Woodall, the gas engineer to the Corporation, and their productiveness doubled, the whole costs having been charged against the revenue of the period. New works are also being erected at New Wortley for 400 retorts.

The greatest daily make last winter was 6,200,000 feet, and the greatest quantity sent out, January 7th, 7,564,000 feet.

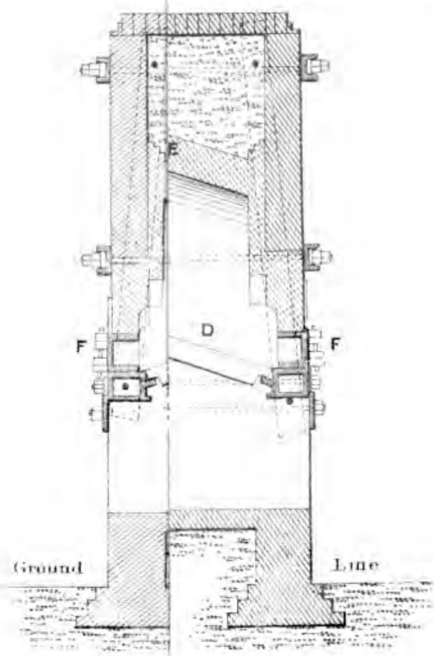
The gasholders are situated at Meadow Lane, Dewsbury Road, New Wortley, Kirkstall, Low Wortley, York Street, Stainburn Square, and Sheepscar. They have a united capacity of 6,000,000 feet. The largest holder station is at Sheepscar, about one mile and a half from the works at York Street, and two miles from those at Meadow Lane. There are two holders at this station, one 180 feet in diameter, and having a united capacity of 1,750,000. At Dewsbury Road there was erected in 1878 a holder 110 feet diameter, having three lifts, which has worked most satisfactorily. The increase in gas made and sold for the year ending 31st December, 1879, was 100 millions, which is equal to the largest increase in any one year at Manchester.

Although the expenditure upon works affecting the health of the town has been enormous, already amounting to about 1,829,000*l.* (not including the cost of paving and flagging new streets done by the owners), it is satisfactory to find that the money has not been expended in vain, for during the last ten years the death rate has considerably decreased. In 1870, it was 28·2 per thousand; in 1871, 26·1; in 1872, 28·0; in 1873, 27·2; in 1874, 28·5; in 1875, 27·5; in 1876, 25·0; in 1877, 22·2; in 1878, 23·7; and in 1879, 22·3.

In conclusion, I have taken considerable trouble to obtain all the information herein contained from the most reliable sources, and believe that it may be relied upon.

DESTRU

TH 4 CELLS



Scale ¼ Inch 1 l

Walter W. Masser Lith Leeds

Having now prepared you a little for what you will see in and about the town, I can only say that during my year of office I will do my best to further the objects of this Association, and I will also attend as many of the district meetings as my engagements will permit.

I welcome you cordially to our town, and trust that you will carry away with you a pleasing recollection of your visit to Leeds at the Annual Meeting in 1880.

ED.—*The President communicated through the Secretary that it afforded him pleasure to present to the Association the lithographs illustrating the destructor and the carbonizer.*

ANNUAL MEETING AT LEEDS,

May 27, 28, and 29, 1880.

TOWN SEWERS.

By THOMAS HEWSON, Assoc. M. Inst. C.E.

The Author has been tempted to bring this subject before the Association partly by the great disparity to be found in the sizes of sewers now laid in well-defined urban districts, and partly from a desire to elicit opinions on the separate and combined systems of sewerage, feeling confident that by the investigation this Association can give the questions some if not all the causes of varying practice may be removed.

By the disparity referred to as "in the sizes" the author means the difference to be found in the sum of the provision now made in town sewers. This sum he contends ought to be more uniform than it is at present and the object of this paper is to endeavour to make it so.

With this view the following proposition is submitted for consideration: Supposing the objects to be attained and the matters to be dealt with are agreed upon, what is the sum of the provision necessary to be made in the *internal or street sewers* of an urban district thoroughly supplied with water?

The primary factors of this sum are of course population and area.

The population is readily estimated where the present plus the normal increase over a given term of years is to be provided for, but on the threshold of the consideration of this the first factor, great difference of opinion exists, the number or term of years for which provision should be made being a moot point.

The fact that Government generally allows thirty years for repayment of cost of works is used occasionally as an argument in limiting the term of years to that period but few think of providing for only thirty years. The engineer is not limited to time

as a rule but he is expected to make *suitable provision* for the future, having regard to the area of the district. In such a case—Is the provision to be for the population which could be accommodated by the whole area of the district regardless of time, or for that estimated on a term of years?

To provide sewers for a district sufficient for all time would manifestly in many cases be a great hardship to the present generation, for the district of a local authority is very often so large that the increase of population required to occupy it would require a term of hundreds of years. In some districts sewers have to be laid through long reaches to connect outlying or detached localities, or it may be along main roads with houses on either side having large tracts of agricultural land behind them. In such districts are the sewers laid to-day to be sufficient for all time, or sufficient only for such a population of the detached localities as would be due to the term of years allowed for repayment?

If the term of years generally allowed by the Local Government Board for repayment is to be the period for which works are to be sufficient, the time would practically soon come when the sewers so laid would have to be enlarged at the expense of posterity. In either case is the solution to depend on sentiment or feeling? If so, A, having greater regard for posterity than B, will make provision for all time, whilst B, remembering posterity has done nothing for him will do nothing for posterity.

Now Parliament which never dies having by statute relieved communities by enabling them to raise money for the execution of sewerage works and to spread the repayment over a long period of years, demands these works shall be *permanent*. The literal meaning of this word of course has no regard to sufficiency, but we all know that in the case of sewerage systems for towns it is used and taken to mean "permanently sufficient," or sufficient for all time, and the general opinion is that in towns the Local Government Board expects sewers to be so laid, that is, once for all. On the other hand, it is clear that as a matter of strict justice, where the cost of sewerage works is to be spread over a term of years in equal annual payments, the provision to be made ought not to be more than would be necessary for the present population plus its normal increase over that term. In full view of the case the author is of opinion that, looking at the great strain which is now put upon towns to

bring up the arrears of sanitary work, it is not right in a system of sewers to make greater provision than is necessary for the population due to the term of years given for the repayment of the cost, and that as the term now given for such repayment is very short, special parliamentary powers should be obtained for repayment over a longer term, indeed, so long as that in making provision for the estimated population due to it, provision would be made for the whole area or district of the authority.

The next factor is the area of a district necessary for the estimated future population and is the quotient of that population divided by the density per acre. This density will be always of course a matter of estimate, still it must be patent that it is within the power of this Association to place on record such facts and figures as will simplify and render such estimates somewhere near the truth.

The classes of the population of a town are generally so well divided into the residuum, operative, working commercial, and middle class that a fair estimate of the area of any future district could be easily given, if a record was made of the average densities of such classes per acre in several towns distinct in their staple trades and building regulations such as follows:—

DENSITY PER ACRE.

Towns.	Residuum.	Operative.	Working Commercial.	Professional and Middle Class.
Rochdale	200	144	92	60
Salford	138	101	60	18

The factors of population and area being determined, they may be broken up into the following quantities, viz.:—

1st. The quantity of house sewage.
2nd. The quantity of subsoil water.
3rd. The quantity of manufacturers' liquid refuse.
4th. The provision, if any, for the water-closet system.
5th. The rainfall.

1st. Practically no difference of opinion exists as to the quantity of *house sewage*, it being generally accepted as the water supply fouled, the loss in it due to evaporation and percolation is so small that the access of subsoil waters is generally considered an equivalent to these losses in the water supply.

2nd. Whilst generally the quantity of *subsoil waters* may thus

be taken as nil, it must be remembered that the question is nevertheless an important one, as affecting not only the sizes of sewers, but also as affecting public health, for in carrying these waters off not only is the water line in the land lowered but by a greater and more diluted flow the sewers are made less foul.

In the report of a Committee appointed by the President of the Local Government Board in 1876, it says :—

> "The sewering of towns and the draining of houses must be considered a prime necessity under all conditions and circumstances, so that the subsoil water may be lowered in wet districts."

And in the suggestions as to the preparation of plans for main sewerage, &c., by Robert Rawlinson, Esq., C.B., C.E., Chief Engineering Inspector to the Local Government Board, dated 1878, he says:—

> "An ordinary amount of subsoil water may in some special cases be admitted into the sewers with advantage, as the regular flow will tend to prevent any silty deposit, and the dilution will tend to lessen the putridity of the sewage.
>
> "Sewers formed in and along a naturally dry subsoil, if in any degree leaky, are liable to accumulate deposit by allowing the fluids to filter into the subsoil.
>
> "The trench in dry and porous subsoils should, therefore, be made watertight before the invert of the sewer is laid in it.
>
> "Sewers and drains perform good service when they permanently lower the subsoil water within a town or near houses.
>
> "Some sites will, however, require special subsoil drains."

As the dry weather flow of sewage compared with the total water supply will give the quantity of subsoil water to be dealt with the following tabular statement will be of interest:—

Name of Town.	Water Supply per head of population for all purposes.	Dry Weather Sewage Flow, per head of population.
Bedford	20	39
Bilston	9	9
Bradford	33	45
Castleford	14	25
Cheltenham	15	28
Chester	36	42
Chorley	20	51
Coventry..	17	37
Ealing	20	21
Kendal	30	60
Leamington	25	32
Leeds	22	35
Luton	30	66
Merthyr Tydvil ..	19·6	20·8
Rugby	20	37
Salford	20	00
West Derby	30	31
Wolverhampton ..	26	33

With these facts the quantity of subsoil water may be determined, however the author will put the following question to the Association, viz. Whether, excepting where there are absolutely large springs of water tapped and which ought to be dealt with independently of the sewers, the Association, with its combined knowledge can afford information as to the quantity of subsoil waters due from the various strata?

3rd. The provision to be made for *manufacturing liquid refuse*, which in itself is a varying quantity differing not only as the trades of districts but also as their rivers, i. e. their local or natural water supplies, now presents itself to the mind of the engineer in a new form. Before the days of the purification of sewage it was taken for granted that sewers were at the disposal of the manufacturers for the discharge of their liquid refuse. Now, however, the legislature, having imposed upon towns the purification of their sewage, has enabled local authorities to exclude from their sewers all manufacturing poisonous substances, and practically (failing an equitable arrangement) also all manufacturing liquid refuse.

This quantity, however, though very important in deciding the sizes of sewers, has not in any case that the author is aware of been yet decided, but that it soon will be he is quite satisfied, for—1st. The cost of purifying sewage is so enormous; and the quantity of manufacturing liquid refuse is so great, varying from one-fifth to two or three times the quantity of house sewage, that the general ratepayer will not submit to be taxed for the purification of manufacturers' refuse, and so pay part of the cost of their trades. 2nd. Riparian owners will not allow water to be permanently abstracted from streams and placed into sewers. 3rd. If even local authorities, after purifying their sewage, remain passive as to the fouling of streams by manufacturers, Government will not.

In view of these features of the case, and in the absence of the arrangement indicated, how is the engineer to determine the quantity of sewage under this head?

The author is of opinion that it is neither expedient nor right to make provision in a sewerage system for carrying off water abstracted by manufacturers from public streams. That arrangement should only be made with manufacturers possessed of an absolute and full right to the water used by them, and that manufacturers using water supplied to them by the local authority should have a free right to discharge the resultant liquid refuse (not being poisonous) into the sewers.

An engineer using these bases will have removed from his path a great part of the present uncertainties, for it will but remain for him to judge as to whether those trades of the district he is dealing with requiring large quantities of water have means of development by private supplies, or failing this, are likely to increase in the district at the expense of having to purchase water from the local authority.

With regard to increase under the latter condition past experience gives a ready answer to the question of the *water supply* per head of the population *for trade purposes*, and it is estimated to be in

Salford	9½	gallons.
Leeds	6	"
Bolton	6	"
Preston	9	"
Newcastle-on-Tyne	10	"
Blackburn	5	"
Rochdale	3	"

thus showing that nearly seven gallons per head per diem is ample provision to be made under this head.

4th. The next quantity of the sum, viz. the provision to be made for *water-closet sewage* the author almost fears to bring under discussion because the subject as a system is a red rag, and has been thrashed threadbare, the partisans to-day holding tenaciously to their opinions and believing the future theirs, but although as a system it has been such a fruitful source of argument, if the Association will remember that the *system* is not here in question, but simply the quantity of water used by it, it may not take up time which could be better spent on other points of this paper, and greater hopes of this result may be had when it is remembered that engineers do not hesitate cordially to carry out the sewerage works of a district to suit any system or systems there in operation.

The question then is, what quantity of sewage results from, or, in other words, what quantity of water is required by a thorough water-closet system?

The following facts are given in answer to this question :—

Gallons per head per diem to Water-closet Towns, not including Trade Purposes.		Gallons per head per diem for Non Water-closet Towns, not including Trade Purposes.	
Bedford	17	Aldershot	14
Cheltenham	14	Blackburn	15
Croydon	45	Bolton	18
Liverpool	18	Leeds	17·5
Newcastle-on-Tyne	21	Preston	11
Reading	24	Salford	10·5
Rugby	20	Rochdale	10·5
Warwick	22		

From these figures (leaving out Croydon which is well known to be in this regard the most wasteful town in England and which has been put in this list to show what that waste can be), an average of 5·6 gallons per head per diem seems to represent the provision to be made for the sewage from the water closets of a town having entirely that system. This quantity appears small however, and the author therefore invites the opinion of the Association thereon, directing its attention to the very small quantity used at Liverpool and Cheltenham towns of extremely different character.

5th. The provision for *rainfall* in a district calculated to be purely urban within the period for which works are to be provided, ought to be a known quantity varying simply as the rainfall of districts, and as it is the duty of a local authority, not only legally, but in the interest of the ratepayers by preventing damage to their property and in maintaining good dry thoroughfares both winter and summer, to conduct the rainfall of the urban districts to the river, it would appear as if there was no room for differences of opinion as to the provision to be made. Appearances we know however are often fallacious, and they are so in this case, *the rainfall* under the written law meaning *all* the rainfall, whilst under the common law the reading of the written law is to mean all the rainfall *except the unprecedented*, that not known in the *memory of man*. Consequently one engineer, led by a desire to economize, may deem it necessary only to provide for half the rainfall that another does.

Thus then that which seemed matter of fact is a matter of professional opinion, in saying which the Association will recognize that differences of opinion prevail.

On August 12th, 1875, the town of Rochdale was visited by a violent thunderstorm resulting in damage being done to property, for which the Corporation was sued, and although the merits of the case were not entirely those of the subject of this paper, in the summing up by the judge it was said, that it was the duty of the Corporation not only to provide for storms ordinary but extraordinary to the extent of reasonable expectation. What this means to a town will be seen from the following table of rainfall in Rochdale during the past 15 years, which with an average of 39·2 inches of fall per annum, gives the details of an average of 191 days rain in each year.

Of some of the greatest falls, as shown by the table, the *rate per hour* has often exceeded one inch.

RAINFALL PER DIEM IN INCHES.

Days in	·01.	·25.	·50.	·75.	1·00.	1·25.	1·50.	1·75.	2 in. and over.	Total Wet Days.
1864	97	35	13	5	..	..	..	..	..	150
1865	85	33	7	..	..	1	1	..	..	127
1866	136	37	16	5	2	..	3	..	..	199
1867	159	43	12	3	1	..	..	..	..	218
1868	145	34	8	5	..	..	..	..	..	190
1869	135	37	18	4	1	1	1	..	..	197
1870	108	24	13	6	1	1	..	..	1	154
1871	151	26	10	2	2	..	..	..	..	191
1872	170	48	18	4	..	..	..	..	..	240
1873	147	25	14	4	..	..	..	..	..	190
1874	144	34	13	4	1	..	..	..	..	196
1875	156	25	15	2	1	2	..	..	1	202
1876	120	36	15	5	6	..	..	1	..	183
1877	147	42	17	11	4	1	2	1	..	225
1878	142	36	10	5	..	..	..	..	..	193
1879	164	16	18	2	2	..	..	..	..	202

The proportion of rainfall finding its way to the sewers of a well sewered purely urban district as given in the Report of the Commissioners of Sewers for London, 1848, may be taken as 78 per cent. of the rainfall.

In designing *internal or street sewers* the author submits as a proper basis—

1st. That the greatest storm repeated, say in 20 years, should be provided for.

2nd. That of this flow not more than 50 per cent. of the resultant flow from the storm will pass off into the sewers in the first hour.

3rd. That such sewers should be capable of carrying the rainfall to the rivers from an area capable of containing not only the present but the estimated population at the end of the term.

This the author knows is a much greater provision than it is generally thought is given by engineers, but the fact that such a provision is given by them is readily seen, when on the author's basis a town sewer at

100	yards distance with a fall of 1 in 150 is only			9 in.	diameter.
200	"	"	"	12	"
300	"	"	"	15	"
500	"	"	"	18	"
800	"	"	"	21	"

The agreement however stops at this point, and here starts in practice the difference of provision for rainfall.

Up to 2 feet the engineer is true to theory, but beyond this he is content to draw upon the extra size of the sewer due to its provision for the future, and upon the brooks, ditches, and agricultural lands, which may now without injury be used, but all of which will be lost in the future buildings and streets which the estimated future population will absolutely require.

This process, where provision is being made for 50 or 75 years, is a very safe one for the engineer, but hardly such as the profession is given credit for carrying out.

What the author insists upon is that, given the term of years to be provided for, it is the duty of the engineer to calculate the population and area required, and these being ascertained to unflinchingly make provision in the internal or street sewers for such a quantity of rainfall as would run off that area in the case of storms so extraordinary as to be say 20 years apart.

Leaving the subject of internal or street sewers, the author now directs your attention to the question of the size of *intercepting sewers*, distinguishing them from *outfall sewers* by assuming the former to terminate at the last point of discharge from the *internal* or street sewers, and the latter to commence at that point and to terminate at the sewage works.

Under the true dual or separate system the sizes of internal sewers *for sewage* the author thinks he may say are agreed upon, and therefore, that on this system no difference of opinion as to the provision to be made in *intercepting sewers* can arise amongst engineers. In the combined system, however much difference of opinion exists, as to the sizes of the intercepting sewers, because, whilst on the one hand manufacturers want the rainfall discharged into the rivers at the highest possible points and during the smallest showers to secure which means small sewers, and the local authority of to-day wants the cheapest scheme, which also means small sewers; on the other hand it is quite clear that technically the engineer ought not only to make his sewer of such a size as will admit of the greatest flow of sewage at the end of the term to be provided for, but so large as that before a storm or relieving outlet should operate, that flow could be diluted up to the standard of technical or legal purity admissible into streams. Out of the struggle the engineer has with these views, arises the difference of the provision made in this class of sewers, and in the absence of any absolute standard too much leaning for the good of posterity, is made towards a low standard. The only authoritative state-

ment in regard to a standard is that given as a recommendation by the Rivers Pollution Commission in their report.*

At first sight this standard appears to be so high as that it would be financially impracticable to make intercepting sewers large enough to reach it, but this is not so, for the author has had the mid-day dry weather flow of town sewage analyzed, and finds that not only in those cases, but in those of the sewage of water-closet and privy towns given in the above-named report, dilution of 20 times the flow will give this standard; and here the author also wishes to mention that 20 times the greatest sewage flow from a purely average urban acre is equal to $\frac{1}{20}$ inch rainfall per hour from such acre.

The intercepting sewer in the combined system has also, when the rivers are in flood, the duty of carrying off the rainfall from the low flat reaches of holme land abutting on them. This however is more an apparent than a real difficulty or cost, for by arranging storm overflows from the internal or street sewers at such a distance from the rivers as will give a level capable of discharging into the streams when in flood, the area of these low lying lands will be so limited as that the rainfall from them will not exceed the volume of the—so to say—diluted upland sewage, therefore, the moment the rainfall on the low flats on the edges of streams exceeds the determined dilution, space is made for it in the intercepting sewer by the withdrawal from that sewer of the upland diluted sewage, the one thus making place just sufficient for the other.

Now, with the law in its present state, is it reasonable or right to make so great a provision in intercepting sewers? Remembering on the one hand the work is to be permanent, and on the other that in many cases less provision would be satisfactory to the present riparian owners, is it for the true interest of ratepayers that this class of sewers should be made sufficient to satisfy the law of to-day; or, hoping for an easement of the law, should they be made too small for such satisfaction? Is it likely that the law will be so eased? For many years it has been the general opinion that such a relief would be given; but where is it, or what sign is there of its coming? Corporations hoped, for some years previous to 1876, that the first Act of Parliament passed would bring it. Has the Rivers Pollution Act brought it? Certainly not; it has almost brought the opposite, for whilst leaving the standard of

* Fifth Report of the Rivers Pollution Commissioners, 1874, vol. i., page 49.

purity where it was—viz. in common law—it has provided riparian owners with a cheaper and more speedy means of compelling local authorities to desist from fouling streams with sewage.

Pointing to the action of the Local Government Board it may be said it has become less exacting since the passing of that Act, but it must be remembered this is more apparent than real, for it is questionable whether the Board has given or ever will give the written certificate of satisfaction to a town adopting anything short of irrigation; and then if it has or will it is quite clear the common law gives riparian owners a right to the purity of a natural unpolluted stream, and the certificate, therefore, if given can only be a protection against the penalties of the Act of 1876.

Answering the question as to the true interests of the ratepayers as to size, the author's view is that an intercepting sewer ought to be of sufficient capacity to carry off the greatest estimated flow of sewage at the end of the term to be provided for, diluted to the practical standard suggested in the Report of the Royal Commissioners on the Pollution of Rivers, and of the rainfall of the holme land above described.

It is clear that the intercepting sewer of the combined system with such duties must be a larger one than that of the dual system, and out of this transparent fact and the idea that the flow of the intercepting sewer *must be dealt with at the purification works*, the question of cost rises giantlike before the mind. Now to the uninitiated these two items of cost when capitalized are so alarming as to cause a flight at a tangent, which is generally accelerated by the engineer, who, feeling the law is too exacting on the point, thinks that if sufficient is done to remove complaints for a few years to come, the law in the meantime may be made more easy to comply with. With your permission, however, we will not take such a flight, but will go over the whole question step by step.

The small intercepting sewer of the dual system can only be achieved by putting duplicate sewers in every street in the town, therefore it is unwise simply for this object to give up the combined system with its one sewer without taking into account the cost and efficiency of the two systems as a whole.

What about the relative merits of the two systems of *internal street sewers?* In the combined system you have one sewer flushed by every rainfall; in the dual system you have two sewers, one for the rainfall and the other for sewage and subsoil water, the

latter, by reason of the abstraction of the rainfall, requiring an annual expense for flushing, a work never systematically attended to, and if it was it is not possible to purify such sewers so well as by the rainfall, and consequently, more sewage gases will generate in them than in those of the combined system, for, as in reference to subsoil water, it has already been said, dilution tends to lessen the putridity of the sewage.

* Again, supposing two sewers in a street, and two sets of drains from each house on each side of such street, the house drains must interlace the duplicated sewers, the foul-water drain communicating with one the surface-water drain with the other. Under such circumstances it would be almost impossible to prevent builders and workmen from entering the sewers with their drains indiscriminately. Moreover if the duplicate sewers were not absolutely watertight, and the subsoil also watertight the fluid in one sewer would, by filtration and percolation, act and react upon the other sewer.

And now with regard to the cost, the stock argument in favour of the dual system. Most certainly two street sewers sufficient for the work to be done must cost more than one such sewer, and with regard to private or house drains, what about the relative cost there? A town of 15,000 houses neither sewered nor drained, on the dual system would cost 30,000*l.* more than the combined system, and in the case of such a town with its houses already drained, on the introduction of the dual system the new outlay to be made would be the same sum as against nothing on the combined system. Will any one say that such an unhealthy system, such extra cost, and such future difficulty of maintenance, is as economical as the extra cost of providing a simply larger intercepting sewer? But many engineers will say the dual system—like many other things—should not be carried to extremes, only the rainfall from the streets should be kept separate from the sewage; yes, but if that is so what becomes of the argument of keeping down the sizes of intercepting sewers, and the quantity of sewage to be sent to the purification works and so the cost, when taking the urban area of the author's district, the street area is only the $\frac{1}{10}$ part, so that such an arrangement would only reduce the volume of the intercepting sewer to that extent.

It will however be said that the dual system gives the rainfall to the rivers to the advantage of manufacturers, whilst the combined system does not. This is only very partially true, but if it is

* Vide 'Suggestions as to the preparation of District Maps, &c., by R. Rawlinson, C.B., C.E., Chief Engineering Inspector to the Local Government Board, 1878,' page 7.

perfectly so, the dual system in its rainfall sewer is an illegality induced by what the author has shown to be false notions of economy, and an erroneous conception that the combined sewer *must* absolutely rob the manufacturer of the rainfall due to the river. As to this illegality, it has been proved by analysis, that town street washings are as foul as London sewage, and so, as polluted liquid refuse ought, legally speaking, to be kept out of the streams, and as to the robbery of manufacturers' water it has been shown that in the combined system all internal sewers before discharging into the intercepting sewer are naturally supplied with storm outlets or leaping weirs, which can be made to act not only in the slightest shower, but be so varied if riparian owners' demands become more severe, that in the absence of any laws on the subject, or of perfect laxity in the law, the manufacturer may have, not only the rainfall but the sewage as well if he wishes, and yet the ratepayer be possessed of works which will enable him at any time to withstand any action at law, or standing between riparian owners and manufacturers, accommodate the standard to the parties. It is true the rainfall would, in a perfectly combined system, from the narrow strips along the banks of streams, have to pass into sewers below the flood level, but even in this regard in most cases very little distance would have to be travelled by the intercepting sewer before storm or relieving outlets made in it would discharge such rainfall into the streams.

The question of economy the author has shown should not be limited to the intercepting sewer, or to the assumption that liquid once admitted into it must of necessity be dealt with at the purification works, and in regard to the latter the author points out that there is no difficulty in fixing on the intercepting sewer immediately it receives the discharge of the last internal or street sewer, a mechanical arrangement of valves and levers arranged to divert the diluted sewage to the river the moment any fixed degree of dilution has been arrived at, and that from this point to the purification works the outfall sewer need not be laid of larger dimensions than would be necessary in a perfect dual system, if such an one is ever carried out.

With such a combined system as the one indicated, it seems to the author that cost, law, health, and full provision for the future are more satisfactorily dealt with than by any other system.

ANNUAL MEETING AT LEEDS,

May 27, 28, and 29, 1880.

THE SEPARATE SYSTEM, AND THE ECONOMICAL DRAINAGE OF TOWNS.

By R. VAWSER, M. Inst. C.E.

There is probably no subject at the present day which excites more lively interest amongst Sanitary Engineers, and none on which more difference of opinion prevails, than the question of admitting rainfall into sewers. On the one hand, it is argued upon sanitary and economical grounds that sewage and rain-water should be kept entirely separate and be conveyed by separate channels to their respective destinations, while others maintain that a duplicate system of sewers secures no substantial advantage at all equivalent to the increased expense it involves. The variable quantity of liquid town refuse is the chief argument of those who advocate a duplicate system; they contend that if large shallow sewers are provided for rain-water, very small drains will serve for domestic sewage, which varies but slightly from day to day, and that this may be purified at moderate expense, while rain-water if discharged into the natural watercourses unmixed with house sewage, does not require purification.

House sewage forms but a very small proportion of the liquid refuse of a town, and were it alone to be considered very small sewers would suffice. Mr. Isaac Shone, the inventor of the "ejector" and the advocate of a system of sewage removal by compressed air, has published tables to show that a population of 25,091 with a daily water supply of 15 gallons per head, may be drained through an 8-inch pipe laid at a gradient of 1 in 100, and that the same 8-inch pipe at a gradient of 1 in 40 would suffice for a population of 39,680. Mr. Shone's system excludes every drop of surface water, and, as his main drain is smaller than the water supply pipe most engineers would consider requisite for the same population, he no doubt excludes all liquid refuse except house

sewage, also all subsoil water, regardless of the expense it may involve. The author has never met an engineer of acknowledged experience in sanitary matters who ventured to confirm Mr. Shone's extraordinary theories, and he regrets that Mr. Shone's apparatus and his system generally, which if judiciously applied might prove a valuable auxiliary in some districts, should remain beyond the range of practical discussion.

The liquid refuse of a town for which provision must be made consists of house sewage, subsoil and surface water, and sometimes waste liquids from manufacturing processes. If the law were rigidly enforced, manufacturers might be called upon to purify their waste liquids before turning them into a sewer or watercourse, but as it would in many cases be quite impossible for want of space to construct the apparatus necessary for cleansing the polluted water, the effect of such a regulation would be to close a great number of manufactories and seriously to depreciate the value of property. It is therefore generally acknowledged that whatever system of purification be adopted provision must be made in manufacturing districts for waste liquids that cannot be conveniently disposed of otherwise.

The less diluted sewage becomes, the more valuable it is at the outfall, or, more correctly, the less its manipulation will cost. It is obviously unreasonable that all rain-water falling within a town area should be purified, but town authorities having been held liable for damage to streams polluted with surface water, and Professor Way and other eminent chemists having proved that water flowing from street surfaces at the commencement of a shower is in every respect as impure as ordinary domestic sewage, an arrangement whereby rain-water falling in light showers shall be conveyed to the purification works, and heavy falls of rain to the natural watercourses, becomes a matter of primary importance, and this the author submits can be better effected by a common sewer with storm overflows, which come into operation after a sufficient degree of dilution has been attained, than by a duplicate system however carefully designed.

From detailed observations at Warrington, extending over the years 1875–6–7–8, rain appears to have fallen, on an average, 208 days in each year, but on 164 days moderate showers amounting to less than $\frac{1}{4}$ inch per day fell. This may be taken to indicate the proportionate number of heavy and moderate showers throughout the country, and as the natural watercourses are not usually

flooded during moderate showers, surface water will foul and pollute them, whereas if rain during slight ordinary showers were collected in the common sewers, it might be purified without much additional expense. With heavy rainfall the stream is swollen with upland water, and will suffer no deterioration if surface water is discharged into it, whether by a separate system of sewers or otherwise, but during slight showers the case is different, and the very means by which it is sought to prevent foul water polluting a stream, may, in dry weather especially, increase the evil. It is very doubtful indeed if the separate system would have an advocate if the idea of purifying sewage profitably could be put on one side. The author submits that the profitable disposal of sewage ought not to enter into the controversy at all, the chief if not the only object being to prevent the pollution of streams with town refuse.

In designing a sewerage scheme, the conveyance of surface water, together with many other details, must depend on local circumstances, but as a rule the author has found it expedient to construct the outfall and intercepting sewers large enough to carry $\frac{1}{4}$ inch of surface water to the purification works in 24 hours, any excess of rainfall being turned into some convenient watercourse by storm overflows. Of course with this arrangement the main district sewers must be large enough to receive and carry the largest probable rainfall to the overflow weir. With a rainfall of $\frac{1}{4}$ inch in 24 hours, or $\frac{1}{100}$ inch per hour, surface water is exactly three times the bulk of the maximum flow of sewage from a population of 60 persons per statute acre, with a daily water supply of 15 gallons per head, and the author believes sewage thus diluted may be safely turned into any stream, always providing the first washings of the surface are conveyed to the purification works.

A case has arisen within the author's experience where accurate estimates have been made of the cost of draining a district by both systems. Dukinfield near Manchester, the place referred to, for which the author has recently designed a system of drainage, is a manufacturing and mining town inhabited chiefly by the artizan class. Each house is furnished with its separate paved yard, and the streets are paved with square sets. The mean altitude of the district is 375 feet above sea-level, and a neighbouring rain-gauge at an altitude of 884 feet gives an average annual rainfall of 45·78 inches for the six years ending 1878. A rainfall of $1\frac{1}{2}$ or 2 inches per day is no uncommon event in Dukinfield, and there

are instances where 1 inch has fallen in less than an hour. The public water supply amounts to about 15 gallons per head per day.

The Local Board, having acquired 47 acres of land for sewage purification works, required to be advised as to the best means of sewage purification, and generally as to the disposal of the sewage of the district.

Upon investigation it was found that the whole district could be drained by gravitation to the proposed purification works. The west side, consisting of about 184 acres with a present population of 7000, constitutes a low-level district, and the remaining 650 acres with a present population of 13,000, a high-level district. The high-level district is for the most part pasture land and at present drains into two irregular surface brooks, which fall into the river Tame. These brooks often overflow, and cannot carry off more water than at present. The greater part of the water falling on the low-level district reaches the existing sewers, and is discharged into the river.

The author proposed for the low-level district 6434 yards of intercepting sewers, capable of discharging the sewage of 12,000 inhabitants and $\frac{1}{24}$ inch of rain-water per hour, and for the high-level district 6163 yards of intercepting sewers for the sewage of 38,000 inhabitants, together with $\frac{1}{12}$ inch of rain-water per hour over 225 acres, and $\frac{1}{24}$ inch per hour over 425 acres. The low-level sewers, exclusive of land and purification works, were estimated at 19,950*l*., and the high-level sewers at 13,400*l*.

The district is very undulating, the average gradient being about 1 in 25, the surface water consequently flows off very rapidly. In the low-level district, the quantity of surface water to be treated as sewage may be restricted by storm overflows to any extent desired, but the existing brooks in the high-level district as already explained are scarcely sufficient to drain the district as agricultural land, and when the ground is built over will be altogether too small, entirely new drains must therefore be provided for the heaviest rainfall likely to occur, as well as for surface water from ordinary showers. Not that all the mixed sewage and rain-water must necessarily be purified, as an arrangement of valves will divert the whole or any part of it direct into the river, without it passing through the purification works.

Exception may possibly be taken to the quantity of rainfall provided for, but in the district referred to it is not considered

excessive. In some instances no doubt a less depth of rainfall may be safely assumed, but in all cases the principle that rainfall must be carried off will remain, and it is only necessary to determine whether to carry it off in the common sewers or to construct separate sewers for it. In the case of Dukinfield, very careful estimates of both systems were made, and it was found that in the low-level district which skirts the river, from which it is in no part more than 300 yards distant, the cost of both systems was practically the same, and amounted to about 19,950*l.*, while in the high-level district, where there are no means of discharging flood water, the cost of the duplicate scheme amounted to 21,700*l.*, or nearly two-thirds more than the other.

In thus comparing the cost of the two schemes it must not be forgotten that the estimates refer only to the main intercepting sewers, such as are usually constructed at the expense of the ratepayers generally, and do not apply to sewers in private streets, constructed at the expense of the landowner. The high-level district, when completely built over, will contain about 50,000 lineal yards of streets not yet laid out, and assuming the additional sewers which the duplicate system involves will cost 10*s.* per yard, a total additional expense of 25,000*l.* will be incurred. It is true this sum would not be paid out of the rates, but would take the form of an increased house rent, which is much the same thing. The cost likewise of separate drains for each house must be taken into account; water falling on street surfaces forms but a small proportion of the whole rainfall, and to be consistent and make the separate system really effectual all surface water from streets, roofs, backyards and elsewhere, should be strictly kept apart from the sewage. What additional expense this will involve it is difficult to say.

Looking merely at the cost of the intercepting sewers, and ignoring private streets and house drainage, it cannot be denied that the separate system may be economical where surface water can be discharged at frequent intervals and where the surface to be drained is not more than 200 yards or thereabouts from the stream, but an authority adopting it will be liable for the consequences of pollution arising from the discharge of surface water into the stream, however perfect may be the system, and whatever the expense of treating the domestic sewage. The author has in several cases been forced to consider the propriety of adopting the separate system, and in thinly populated rural districts has some-

times been able to leave surface water to follow its original course, but in urban districts, where surface water as well as sewage must be provided for, his general experience is not favourable to the separate system.

It is alleged that gases injurious to health are sometimes generated in large sewers, but no sewer should be in direct communication with a dwelling, and if this law is observed there will be no greater danger from a large well-constructed sewer than from a small one. Upon the form, size and construction of a sewer too much pains cannot be bestowed; the invert should expose the least surface for friction and the sewer be lined with salt-glazed or smooth vitrified bricks. Such a sewer, with a velocity of flow not less than 2½ or 3 feet per second in ordinary dry weather, and with occasional flushing, will give the best sanitary result. Old drains ill-constructed and honeycombed with rat-holes which often form a communication with adjoining houses are extremely dangerous, and ought seldom to be retained. When pumping is necessary it is the more important to minimize the flow of sewage by excluding as much rain-water as possible, and in such cases surface water may require exceptional treatment, but cases are very rare in which a well designed system of common sewers with flood water overflows is not better adapted for discharging surface water than a duplicate system of sewers.

Referring to the idea that the expense and difficulty of sewage purification is increased by the admission of surface water, the author submits that until it is authoritatively ascertained that town authorities cannot be prosecuted for turning surface water into streams, all sewage purification works should be capable of treating foul surface water such as is collected after moderate showers, but that when a safe degree of dilution has been attained the excess may be turned direct into some natural watercourse.

The Author submits the following Conclusions to the Judgment of the Association.

That a perfect system of town drainage must provide for the removal of *all liquid refuse,* together with the largest rainfall known to have fallen in the district.

That rain-water falling on paved surfaces in thickly populated districts is known to pollute fresh watercourses, and in the present state of the law should be purified before it reaches a stream.

That sewers and sewage purification works should be designed to deal with the maximum flow of sewage due to the population, together with waste liquids from manufactories that cannot be otherwise conveniently disposed of, also with a rainfall at the rate of $\frac{1}{100}$ inch per hour or $\frac{1}{4}$ inch per day over the whole district drained.

That falls of rain greater than $\frac{1}{4}$ inch per day may be safely turned into natural watercourses, and sewage diluted with $\frac{1}{4}$ inch and upwards of rainfall may be diverted into watercourses without undergoing purification.

That a system of town sewers for the separate removal of surface water possesses no advantage over common sewers capable of removing every class of liquid refuse.

DISCUSSION.

Mr. J. Lobley observed, with regard to the separate system of laying down sewers, that it was some years since he had endeavoured to obtain the opinions of the Members of this Association upon the subject, and he was glad to find that it was now before the Meeting. It would be very interesting to ascertain the actual opinion of the Members of the Association. For some time past the separate system had been growing in favour, and in fact any one who ventured to speak against the separate system might be considered to be behind the age. There was no doubt that in the South of England, where manufactories were comparatively scarce, the separate system was a useful one, and in other large districts or very wet districts, where subsoil water was large, and where the amount of water supplied was large, as at Oxford, there was no doubt that the separate system was a good arrangement. Owing to the difficulties which had been mentioned by the authors of the papers with reference to the separate system he had not been able to advocate it strongly, although he believed it to be extremely useful. It was always well "to be off with the old love before you are on with the new," but he considered that each place should be taken on its own merits, and that the separate system might be a useful arrangement for all those places within a certain distance from the stream. That was the practice he was carrying out, and although the town generally will use the combined system, the new portion of it which lies nearer to the stream will use the separate system. Mr. Hewson had referred to the expense, and

the difficulty with regard to builders and workmen supposing two sewers to be laid in one street. He had experienced this, and found the greatest difficulty in getting builders to distinguish one sewer from another in putting in the drains, and sometimes it was necessary to alter the connections.

Mr. A. M. Fowler thought the papers very interesting. In considering the separate system and the combined system they must remember that there were no two towns of the same level. The ground was undulating and the sewers varied in their inclinations. The town of Leeds, for instance, could not have the separate system, for it would be simply an extravagant waste of money. In the Woodhouse district the average height would be 300 feet, whereas other districts would be 400 or 500 feet, and the lowest perhaps 80 feet above the level of the sea. During a long drought such as had existed of late the large number of water-closets within large towns must naturally foul the sewers to a certain extent, and they would be at a loss to know how to ventilate the sewers. Suppose there was a drought for two or three weeks and a slight shower came, and it was turned into the rivers instead of into the sewers. That would be a fallacy, as all the water that could be obtained was required to flush the sewers. With regard to subsoil water, they all knew, or ought to know, that it was far better to keep it from percolating into the drains. He did not think the question of rainfall had been dealt with fully. A great deal more might have been said on that question. It was not the quantity of rain which fell in a day, it was the quantity which might fall in half an hour or so. Sewage from houses formed a very small quantity, but it had a very great power of throwing off a large amount of foul gas, and thus sowing the germs of typhoid fever in the house. What they had to provide for was a thunderstorm. They might have an inch and a half of rain in a day, but it might fall regularly so as not to affect the sewers, whereas in a thunderstorm a quarter of an inch of rain might fall in a quarter of an hour. The sewers must be equal to pass that off, and they must make their calculations accordingly. In answer to Mr. Lobley's remark as to manufacturers in towns being prohibited from turning their refuse into sewers, he could say Leeds was a fair example of that, because the Leeds and Calder Navigation Company had several Acts of Parliament which prohibited manufacturers from turning water from *streams* into sewers. They were bound to turn it back into the streams. As to the standard of purity to be admitted into a

river, of course they all knew that the standard issued by the Rivers Pollution Commissioners, who had been through this district amongst others, was very stringent indeed and one that could not possibly be carried out. If they were simply to put a lump of sugar in a gallon of water that gallon of water would not be admitted into the river under the standard of purity, and therefore it was impossible to act up to the standard. The rinsings of a teapot into a gallon of water would not be admissible into a river, and therefore the standard was impracticable. He had designed several large sewage schemes—for instance, Salford—with the view of having weirs, so that when the sewage water rose in the sewers to its full extent, say within a few inches of the top, the flood water would pass off by means of a sort of self-acting leaping weir, and so discharge the flood water into the streams. The Salford sewer is 8 feet 6 inches in diameter, and is designed so as to take a certain quantity of rainfall in a district supposed to be urban every day for thirty years, and when the thirty years expire they will have to make additional leaping weirs and arrangements to pass away the rain, which he thought they would have no difficulty in doing.

Mr. J. Lemon remarked that Mr. Hewson had raised a very important question, and that was—what provision should be made in a town or district when they where laying out a system of sewers for such town and district, and that the scheme provided should have some reference to the number of years for which they borrowed the money. He thought that was a fallacy, for when any one was called to provide for a district he must look to the area of the district, and he must provide for the whole of the district. The Local Government Board would not receive any scheme which did not make adequate provision for the district to be drained. Moreover, if they did do so they would be placed in the position that at some future day they would have to take up the sewers and relay them, because they would not be sufficient for the work they would have to do when provision had to be made for the whole of the district. He had had no difficulty in getting the Local Government Board to allow Corporations and others with whom he had been connected to borrow money for fifty years for permanent works. Fifty years was sufficiently long, and taking the rapid growth of towns they might reasonably suppose that the district which was to be provided for by the scheme would be covered by that time, and it was their duty to provide for the whole of the drainage of the district. He had not found any difficulty in

making a correct estimate of the population to be provided for. Mr. Hewson had told them the proportion in his town of the working class, the middle class, and so on. That was a pretty theory, but he was at a loss to see what it had to do with the question. He had gone to work and had divided his town into drainage areas, and had proportioned the population to each of these drainage areas, according to the class of persons who inhabited the different parts—that was to say, the number of houses built upon a portion of that district. For instance, he took district A. Part was built upon and part not built upon. He looked upon the population approximately from the portion built upon, and found the proportion per acre, and it was fair to assume that the remaining portion of that drainage area would be covered with the same class of property—in fact, they could form a pretty correct judgment of the class of houses to be built from the houses already built, and the number per acre to be provided for in that district. That was the test which was adopted by Sir Joseph Bazalgette. Mr. Hewson raised a very important point as to the water to be taken from manufactories, and he made a suggestion which was a very fair and reasonable one, and that was, that the Local Board should take away a quantity of water equal to that supplied by them, that was to say, that if a Corporation in the possession of their own water-works should provide a manufacturer with one million gallons for his works, it was only fair that they should take away the dirty water from him when he had done with it. He thought there was some reason in that, but no reason in making the general ratepayers take away water from manufactories entirely. He thought that would be taxing the general body of ratepayers for the purpose of the trade of that particular individual. He considered that the manufacturer ought to provide for a certain purification of his refuse water before he discharged it into the sewers, and if he did not do so he ought to pay a special rate. Again, as to the proportion that the double system bears to the single system. Mr. Hewson said that the streets were only one hundredth part of the area of the town.* He did not know how Mr. Hewson arrived at that fact, but it did not agree with his experience. The area of streets bore a very much larger proportion than that, more like one-tenth. Again, he did not take into consideration the amount of evaporation which naturally took place in gardens, backyards, and other places not paved, which really never found its way into any drain at all.

* Owing to a clerical error $\frac{1}{100}$ was written for $\frac{1}{10}$ in Mr. Hewson's paper.

Again, there were houses with pipes coming down the front of them, the water from which found its way down the street and into the sewers where the separate system was in vogue. Alluding to the question which had been raised as to the merits of the separate system as against the combined system, he remarked that he had carried out the drainage of towns on both systems, and had had an opportunity of comparing one system with another, but there was this extraordinary fact in his experience in reference to the single system, and that was that he had no sooner got his single system finished than he began to make efforts to do something else. In all streets immediately contiguous to the streams he began to put in sewers to divert the drainage from the streets into the streams. He believed that was the experience of many of them. It was not so much the quantity of rainfall which was the difficulty in their sewers, but the large amount of sand and washings from the streets which was taken into the sewers and stopped them up. That was what they were anxious to avoid. He had occasion in the town of Southampton to examine a sewer, and found that there were heaps of sand in immediate connection with the gullies. He had the sewer properly cleaned out, and diverted all those gullies into the stream, and the result had been that the sewer had been comparatively clean ever since. He thought that some of them went on the fallacy that the separate system was entirely a separate system. There was no such thing as a town drained on the separate system. There were plenty of towns drained partially on the separate system. In the city of Winchester, which presented facilities for the separate system more so than any other town he had seen, by reason of the number of open streams running through it, they were able to get rid of the surface water in a way that they could not in other towns. In that city there was not a single gully connected with the sewers. They had taken every possible advantage of local circumstances, and had done everything they could to keep out the rainfall from the sewers. Some people called it the separate system. He said it was nothing of the kind. It was impossible to prevent connections being made with the sewers, or to prevent houses being drained into the sewers in all directions. They might lay down bye-laws and regulations, but all those bye-laws fail in working. If they carried out the separate system in its integrity they must have a duplicate set of sewers and drains, which in his opinion was an absurdity and could not be carried out. He was an advocate of the separate system wherever it could

be carried out, and he would take advantage of what nature had provided for carrying it out. He put this question to the Association. When they went into a town what did they find? They found that the rainfall went away somehow or other. There were few towns, however primitive their drainage, where some provision was not made for the rainfall. The very first thing that was done was for persons gradually to make use of surface drains and connect their houses with them. Then the drains which were put in for rainfall only became polluted and in a foul state, and there was an outcry about an ill-drained town. In answer to that he would say, why not go back to the position they occupied before, and allow the rainfall drains and sewers to do the work which they did before effectually. If they laid down an entirely new system of sewers to take away house refuse, and left the rainfall to go where it hitherto did, they would find that they got over their work very simply. There were, of course, exceptions, large towns such as Leeds, and towns of that class, where it would be absolutely impossible to carry out the separate system. He hoped that the Association therefore would not lay down any general principle, saying that the separate system was the best, or that the combined system was the best. They must treat the towns they had to deal with according to local circumstances. Referring to Mr. Vawser's paper, Mr. Lemon remarked that he believed Mr. Shone was doing a very valuable principle a great deal of harm by his injudicious advocacy. Mr. Vawser said that Mr. Shone in the tables he had published endeavoured to show that the sewage of a population of 25,091, with a daily water supply of 15 gallons per head, might be drained through an 8-inch pipe laid at a gradient of 1 in 100, and that the same 8-inch pipe at a gradient of 1 in 40 would suffice for a population of 39,680. He would ask where they were to obtain a gradient of 1 in 40 or 1 in 100. It was most exceptional. He knew Mr. Shone would reply in answer to that; "By reason of my ejector I can get those gradients." And there was something in that. Again, as to the 15 gallons per head. Some towns managed to keep their water supply down to 15 gallons per head, but they knew where waste was great it was more likely to run up to double that amount. He found that when he proposed a system to persons who had seen Mr. Shone's tables they said, "You are very extravagant indeed, because Mr. Shone tells us he can drain a town with an 8-inch pipe for a population of 40,000." He disputed that altogether, and hoped Mr. Shone would not attempt to teach

his brother engineers how to lay down sewers, and although they were very glad to adopt his principle where it was applicable, these hard-and-fast lines should not be sent broadcast, for they had a tendency to mislead. Mr. Vawser had made a statement which he would like to call attention to. It was this: "With a rainfall of $\frac{1}{4}$ inch in 24 hours, or $\frac{1}{100}$ inch per hour, surface water is exactly three times the bulk of the maximum flow of sewage from a population of 60 persons per statute acre, with a daily water supply of 15 gallons per head, and the author believes sewage thus diluted may be safely turned into any stream, always providing the first washings of the surface are conveyed to the purification works." He was quite sure Mr. Vawser did not see the position in which he landed himself. He said that if sewage was diluted by three times its bulk it was safe to go into a stream, but according to the tables just given them of the water supply of Croydon, which had 45 gallons per head, there was no necessity for Croydon being obliged to do it at all, because there it was diluted, and therefore all the sewage of Croydon ought to be turned into the stream, and the works carried out there were simply a waste of money. Even though the sewage was diluted by three times its bulk they did not get over the fact that it had a large amount of excreta with it. Again he found, with reference to the high-level district, Mr. Vawser said, "These brooks often overflow and cannot carry off more water than at present." He thought that was a very great reason why they should be put in a proper condition. It must be the duty of somebody to take care of these brooks, and it was important that they should be large enough to take away the rainfall and so prevent the flooding of the district. If these brooks were properly cleaned out and enlarged it would be found that they formed a very important part in taking away the rainfall of the district. He now came to what he considered the most important part of Mr. Vawser's paper—a part upon which he wished to take issue, and he should like to take a vote upon it, as he did not think it was any use for this Association to meet without coming to some practical decision. Mr. Vawser had said "that a perfect system of town drainage must provide for the removal of all liquid refuse, together with the largest rainfall known to have fallen in the district." In answer to that he would say that it was not expedient or necessary to provide for the largest rainfall known to have fallen in the district. If they were to make provision in the sewers for the largest rainfall, they would require drains of enormous size, and there would be no end to the cost. The same

question was raised by Mr. Simpson when the drainage of London was talked about. One of the main sewers was, he thought, to be 24 feet in diameter. The whole thing was an absurdity. They could not provide for the greatest rainfall in the district except by making storm overflows at available points. If they were to provide for the largest rainfall known in the district he did not know who was to have the job to carry out the scheme. They must have a Corporation with plenty of money, and he could not get Corporations to do anything like that. Another important point was that raised by Mr. Fowler, who said that water-closet sewers were flushed by the rainfall, or in other words, that if it was not for the rainfall they would not have water-closets flushed at all. He took issue upon that, and thought that a sewer properly constructed ought to be able to keep itself clean without the addition of the rainfall at all, and if it did not do that, it was not a properly constructed sewer. He said that the excreta and liquid refuse going into the sewers ought to be discharged at the outlet—and he knew few towns where it was not so discharged—in less than six hours, and that was taking the minimum rate of flow, which was 2 feet per second. If they did not do that what was the good of sewers at all? They would become elongated cesspools. Sewers if properly constructed ought to be kept clean, if there was not sufficient drainage they must flush them, and if they could not do so the principle upon which the town was laid out was radically wrong. He protested against the theory that it was necessary to admit rainfall into sewers to keep them in proper condition.

Mr. A. M. Fowler remarked that Mr. Lemon took issue upon the point he had raised as to rainfall being a benefit to town sewers on the water-closet system. It was of course well understood that all their gradients should be as straight as possible, and that the tubes should be glazed, but however well they might lay their drains he was of opinion that after a long drought these sewers were not so clean as they were after they had been flushed by a thunderstorm. Mr. Lemon had alluded to elongated cesspools. He never hinted at such a thing, and never heard of such a thing. He said that these sewers were cleaner after they had been flushed by a thunderstorm. Alluding to the flood sewers mentioned by Mr. Vawser, he remarked that he thought it quite right that when the sewers got into a state of flood it could be turned into the river. Mr. Lemon forgot that in great floods the river was flooded at the same time that the sewer was flooded.

Mr. A. W. Morant (President) said in his opinion it was not the case that rivers were usually in flood when sewers were in flood. If they took a sharp thunderstorm the chances were that the sewers would be choked when the rivers had not had time to make the least change. He had noticed the same effect in the becks passing through Leeds. With regard to manufacturers' refuse, he should be glad if Mr. Hewson could mention what powers there were to prevent manufacturers putting any refuse they liked into the sewers. He had never been able to find anything strong enough, neither had the town clerk. There had been one case which had been tried, rather an important one, at St. Helens, where manufacturers were restrained because for some weeks they put in two different liquids which taken separately were harmless, but which when the two met created a great nuisance. He should like to know any powers they had to prevent manufacturers putting in any refuse. There were a great many cases in Leeds where lime was used, and they even turned milk of lime and even thick lime into the sewers, which was very objectionable. Mention had been made of the duplicate system at Oxford. He knew that in that case the old sewers were retained and used for the gullies, and the new sewers for the sewage and house water. The same thing was done in Leeds so far as was possible. At the same time, as Mr. Lemon had said, wherever there was an opportunity of connecting a gully with any watercourse or stream of any kind they did that. Referring to Mr. Fowler's remarks about leaping weirs, he stated that a good deal had been written about the subject, but he thought he might claim to have been the first to apply them to sewers. He did that at Norwich in 1866, and an account was published in 'Engineering' in 1870. He took the idea from Mr. Bateman's leaping weirs at the Manchester Water-works. In reference to the one standard of purity, he had some recollection of the Thames Conservancy producing a standard which did not come to anything. He agreed with Mr. Lemon that the full size of sewers required could be very well ascertained at first. They could tell very well what was likely to come upon the area they had to drain, and then if they provided a sufficient number of flood overflows, he thought they had done all that was possible. He did not think there was a town in the world where sewers had been constructed large enough to take any storm that might happen. All that could be done was to provide for anything reasonable, and then after that point allow the waters to pass into the rivers.

Mr. A. Comber stated that counsel's opinion had been taken by the authorities of his town as to whether the refuse from manufacturers should be admitted to the sewers, and the opinion was that unless the waste was so diluted as to be equal to the standard allowed by the Rivers Pollution Act, it must be admitted into the sewers.

Colonel Jones, V.C., said he had been an advocate of the separate system, and was glad to find it coming before an Association so well fitted to discuss it. Hitherto he had always found a desire to shirk the question by everybody, except the advocates of the system. This was the first time to his knowledge that the objections to the separate system and arguments for the old combined system had been put upon paper, and he was delighted to find that that was so because the truth would be ascertained from discussion. When a water supply was introduced into a town, it became incumbent upon that town to provide new ways for carrying that supply in addition to the old drainage system. He thought the question should be treated simply as one of water supply, and if they brought into a town a defined and known quantity of water, they should provide to take it out in the same form. He did not want to enforce absolute theory. They could not in practice do so, but he held that that was the standard which they should try to aim at, and get as near it as they could. They must take a great deal of rainfall and subsoil water into the sewers, do what they would to prevent it, but they should try to have as little foul water to deal with at the outfall as possible. A velocity of flow of not less than 2½ or 3 feet per second in ordinary dry weather with the sewers totally disconnected with the houses would be perfectly right, but they knew that in practice this was seldom or never the case throughout a town, and they could not effectually prevent sewer gases from penetrating into a house. Mr. Vawser had quoted the experiments of Professor Way and other eminent chemists. He was aware that Professor Way had made some experiments, but he also knew that Dr. Voelcker, Consulting Chemist to the Royal Agricultural Society, who was perhaps the highest analytical chemist in the kingdom, in giving evidence before an inquiry at Windsor, had these very experiments brought to his notice, and said he was perfectly convinced there must have been some mistake in making these experiments, and Professor Way did not attempt to defend them. Dr. Voelcker was also asked at the same inquiry whether he thought street water passed directly into a river could be objected to, and he said he did not

believe it ever could be objected to on any account so long as it was not mixed with sewage. Mr. Vawser was anxious that the first washings of the streets should be purified before reaching a stream, but yet he would allow sewage diluted with more than ¼ inch of rainfall to enter without undergoing purification. That seemed rather inconsistent. All they desired to get was an approximation of the actual dilution. Where sewage and rain-water came from a town in which the whole was mixed, he had proved that he could deal with it successfully, but he knew he could deal with it more successfully if some of the rain-water was kept out. He had watched experiments with Mr. Shone's system, and he thought that both Mr. Vawser and Mr. Lemon had misinterpreted his tables. Mr. Shone did not propose himself to lay an 8-inch pipe at a gradient of 1 in 40. He simply computed for tables showing at what rate water would flow from pipes of a given size laid at given gradients. He only did that as an example to show people that they could not get that due velocity of 2 or 3 feet per second without having a certain quantity of liquid in the pipe with reference to its size and gradient. He thought it was unfair to take up these tables and talk of Mr. Shone's extravagant *theory*, because he simply laid down what would be the case under certain given conditions. Mr. Shone's system was equally applicable if they were going to take $\frac{1}{100}$ inch per hour or ¼ inch of rainfall per day. It was quite contrary to his interest to keep the rainfall out, because his system was equally applicable to rain-water, and he would profit by the extra number of "ejectors" required in that case. The essence of Mr. Shone's system was that it competed with the ordinary pump in this way, that if they had to pump in different parts of a town it was not economical to have little engines at different places, but more economical to concentrate the engine power in one place. That was what Mr. Shone proposed to do, and he had proved that it could be done, and simply wanted a town to try it on a larger scale than had before been done. He felt confident that ere long Mr. Shone's system would get this trial from some town or other, and be found as successful in practice on a large scale as it is thoroughly correct in theory and has been practically tested at Wrexham on a small scale.

Mr. E. Pritchard said that the papers just read were able ones, and the subject of them was one which very properly engaged the attention of the Association. He ventured to say that the question

of separate and combined systems of sewers was very much like that of the disposal of sewage, inasmuch as their treatment must be governed by local circumstances. With regard to the planning of schemes of sewers for towns, he thought that a system of sewers should be constructed, as Mr. Hewson had very tersely put it, "permanently sufficient," but the difficulty in consequence of expense in making such a scheme "permanently sufficient" (and not sufficient only for the thirty years over which the money is borrowed) must in itself be apparent to every engineer. He must maintain that the proper principle of providing schemes of sewerage for towns was the "permanently sufficient" method. There were one or two very important points in both papers in reference to subsoil water, and Mr. Hewson very properly quoted from the suggestions of the Local Government Board, that it is absolutely necessary in certain cases for the sake of health to remove the subsoil water. His experience in several towns had been that there is a difficulty in keeping the subsoil water out of the sewers. He found however carefully the sewers were laid (unless special pipes were used for the purpose), that subsoil water would follow the excavation that had been made, and even if the pipe had been carefully laid and jointed the water would insinuate itself around the outside of the sewer and so lower the line of saturation throughout the district. With regard to surface water, it was very difficult to prove that in a large town it was not as impure in many instances as the sewage itself, and he gave as an illustration of this the town of Birmingham, which had been suffering in consequence of the large quantities of sewage and surface water that had been discharged at the outfall, amounting ordinarily to 18 millions of gallons per day, which with a fall of rain was increased to something like 40 or 50 millions of gallons, making it totally impossible to deal with at the present time. It had been argued by the advocates of the separate system, that if the surface water was diminished the sewage might be properly treated, as the surface water would no longer be a source of annoyance. He believed however that not only would a separate but a triple system be required. Assuming that the washings from the streets were not of an objectionable character, in a town like Birmingham, and many other large towns of a similar character, where in many instances in the alleys and courts the gullies for the removal of the surface water are placed, it was a common occurrence for organic matter in the form of refuse water from the houses to be thrown into those gullies, in fact it was thrown on the surface, consequently

it would necessitate three systems of sewers, one for sewage proper, one for the removal of the contaminated surface water, and one for rain-water. The cost of such a system would render it so impracticable that he did not think that any Government would be found willing to impose such a penalty upon a large constituency. He was an advocate for the separate system of sewers, but it must mean that it is the combined system in a certain sense, for he considered it quite impossible at once to remove the surface water and purify it, and although for their guidance they had a standard of purity in the Public Health Act, 1875, a subsequent Act, Pollution of Rivers Act, 1878, made it illegal to turn into any watercourse any sewage or the discharge from any sewer. That being so made it a very difficult thing to deal with the combined system of sewers, and it was a remarkable fact that in the various schemes now submitted by engineers for the approval of the Local Government Board for the sewerage of towns in nearly every case a provision is made by which, although it is called the separate system, the storm-water shall be removed on its way to the outfall. It had been said that there was no instance of a pure separate system being carried out in this country. He believed that such was the fact, and he was not aware of any such system having been attempted, and although an advocate of the separate system in a sense, he would use only those sewers that at present exist for the removal of the surface water, and he would construct sewers of such a character as would effectually remove the sewage and at the same time be self-cleansing. With regard to the remarks made by Mr. Vawser in reference to Mr. Shone's ejector and to the proposal for the removal of the sewage of a vast population through such small pipes, all he could say was that he believed that he was supported by the Association in stating that the ejector as invented and patented by Mr. Shone was a most ingenious and valuable contrivance, and one that would no doubt play a most important part in the future in assisting engineers in the solution of the difficult subject of the removal of sewage. There was no question but that it was an excellent arrangement, and as compared with the ordinary pump, superior to anything he had seen. He could not endorse the opinion that an 8-inch pipe with a certain gradient would remove the sewage of a population of 39,000. He must with Mr. Vawser and Mr. Lemon take exception to that, and he would be pleased to hear what explanation Mr. Shone would give on the point.

Mr. W. H. Fox said that he had had some experience of both the combined and the separate systems of sewers, and was of opinion that where sewage had to be pumped for irrigation or to be treated chemically the separate system should more or less be adopted. The separate system was certainly one of degree, the extent to which it was carried in each case being governed by local conditions. He thought with Mr. Vawser that the surface water flowing off the leading thoroughfares of our large towns should not be separated from the sewage proper, because such surface water was often too polluted to be admitted into a stream without undergoing purification. It was only during the previous week that he had visited a sewage farm, where he had been informed that the great bugbear was that the storm-water was not separated from the sewage, and that often after a marked downfall of rain the quantity of sewage delivered at the farm was quite unmanageable, and its consequent admission into the watercourse the cause of much complaint. Many people had a wrong impression with reference to the separate system, they imagined that it was always necessary to lay two drains in every street, or at any rate that there should be two drains in every street. The town which he represented afforded rather an interesting illustration of the extent to which the separate system might be carried out without the laying of two drains in all the streets. To carry out the single system of sewers at Barrow-in-Furness for the area from which the sewage had to be pumped would involve the laying of about 24 miles of sewers, to carry out a scheme for separating 66 per cent. of the rainfall flowing to the sewers would involve the construction of 30 miles of sewers, to carry out a scheme for separating nearly 90 per cent. of the rainfall would involve the construction of 36 miles of sewers, and to separate the whole of the rainfall from the sewage would involve the construction of 36 miles of sewers plus the laying of two drains in the backyards of about 45 per cent. of the number of houses in the town. Now to separate 66 per cent. of the rainfall in a district like Barrow-in-Furness would involve the laying of only 6 miles of additional sewers out of 30 miles, and these sewers would have to be laid in the principal streets, so that the cost of laying the two small sewers in the place of the single sewer would be very trifling indeed, whilst the cost of the pumping in the case of the single sewer would be very great. In fact, if the cost per annum were capitalized it would exceed very much indeed the cost of laying the

6 miles of sewers. He might state that a part of Barrow-in-Furness was laid on the separate system entirely, every drop of rainfall upon the yards, back streets, and front streets being separated from the sewage. His own opinion was, for the reasons he stated at the meeting last year, that it was pushing the separate system a little too far to separate the rainfall of a house from the sewage of a house. In a town like Barrow, where they had to pump such a large quantity of sewage, he thought that no Corporation having to deal with sewage under similar conditions would have adopted the right system if they had adopted the single system.

Mr. SHONE said that Mr. Vawser in his paper had made allusion to his system and his ejector in such a way as to mislead the Members of the Association. He was sorry to find that Mr. Lemon, Mr. Vawser, and Mr. Pritchard had fallen into an error and had misinterpreted the meaning of his sewerage tables. He believed however that Mr. Pritchard thought so much of the tables that he had had them photographed for his daily use, and he had said that he had already given evidence from them. He thought that was evidence enough that they are not the tables of a mere theorist. They showed what may be expected from the placing in the ground of 4, 5, 6, 7, 8, 9, 10, 12, 15, or 18-inch pipes—that if they laid any one of those pipes on any gradient between 1 in 40 and 1 in 5280 the tables would show what velocity would be obtained providing the population discharging sewage into the pipes was sufficient to fill or half fill them. They also showed by lines he had introduced what are the gradients and the velocities necessary to make a pipe self-cleansing. The tables showed most conclusively how it happens that the sewers are, as some of the gentlemen who had spoken had described them, nothing more nor less than elongated cesspools. If they laid a pipe of a given size on a gradient that was unsuitable to obtain the necessary velocity, they would have stagnation in the sewer. The table did not show on the face of it that the quantity of sewage should be limited to 15 or 25 gallons per head. It had examples showing how they could apply it to any population and to any quantity per head. If 15 gallons was not enough they could put 150, and the table would tell them the gradient at which the pipes ought to be laid down. Mr. Vawser had said that he (Mr. Shone) would put in a pipe which would be smaller than the pipe which a water engineer would put in to supply the same population with water. Now it

was not fair, in the transactions of an important Association like this, to one who was attempting to introduce a new system, to hold him up, not as a practical engineer, but apparently as a mere theorist. Mr. Rawlinson had said of these tables that they are conveniently arranged, and as such they had been approved.

Mr. J. P. Spencer said that the advocates of what was called the separate system had come to this conclusion that they were advocating a system which is not a separate system though they call it so. The notion of the separate system had its origin in the minds of those gentlemen who were under the idea that sewage alone after being treated would give a valuable manure. With the combined system there were difficulties in attaining that result. They only looked to some means of overcoming the difficulties in their own way, to a certain extent forgetting the objects of a sanitary engineer and the health of the general public. What was desired was the general benefit to the public health, so to speak, rather than to produce any system that would assist in the better treatment of sewage, or in other words in the manufacture of manure from it. With regard to the question of separate drainage, it seemed to him that the advocates of it could not show any real reason why it should be entirely separate. They would all admit that a certain amount of rainfall must gain admission into the sewers. On the other hand the advocates of the combined system had he thought arrived at the most common-sense point when they state that the sewage combined with the ordinary surface water may be disposed of by taking it to the purification works, whilst the storm-water or surplus above the average may be disposed of by those outlets which are most appropriately named storm-outlets. It was certainly not the average rainfall of a whole day that created a difficulty, but the sudden flush of half an hour's rain or thunderstorm. With regard to the purity or otherwise of the rainfall, he thought that the cases of large towns like Birmingham and others, although important, do not embrace the whole question as regards the whole area of the country. There were no doubt a great many sewage schemes in smaller places, and it certainly could not be the case that the rainfall or surface water in such places was in such a state of impurity as to make it unfit to enter the local river or stream. He thought therefore that the rainfall so far as its impurity was concerned might safely be carried into the streams. Mr. Lemon had told them what had been done in Winchester, and in other country towns similar opportunities would no doubt be

afforded of disposing of the rainfall. Now in what state would the water go into the stream? It would have to flow a certain distance, and in doing so it would to a certain extent go through a process of natural precipitation—that is, a great deal of the impurities might be carried down to the bottom of the channel along with the heavy matter, sand and other things, with which it might be mixed. The whole of this discussion seemed to him to point to this, that the combined system, taking it all in all on broad principles, is the better of the two, because they had on the one hand the fact that the advocates of the combined system went straight to their object, whilst on the other the advocates of the partial separate system had to beat about the bush, saying that they do not mean a separate system, but something that is not quite a separate system. As to providing for the whole of the rainfall, he thought that was absolutely impossible. There was no doubt that a great deal of the rainfall provides for itself. Certainly no engineer could construct sewers, unless he constructed monstrosities, which would take all the rainfall away.

Mr. Sturgeon said that Mr. Shone did not at all recommend an 8-inch pipe to serve a population of 25,000. That was not the object of his tables, it was simply to show that with an 8-inch pipe laid at a gradient of 1 in 100, and at the rate of 15 gallons per head of the population, it would require a population of 25,000 to keep that pipe flowing full. These were simply data from which they could make their own calculations. The tables did not confine the quantity to 15 gallons per head. They gave the quantities 15 or 25 and the formulæ by which they could ascertain the size of pipe necessary for any other quantities. Then again it was altogether wrong to state that Mr. Shone's system excluded every drop of surface water. His plan was as applicable to the separate as to the single system.

Mr. T. Hewson in reply to the discussion said that Mr. Fowler in suggesting that all sewers should be sealed so as to exclude the subsoil water did not tell them whether or not he would have a separate sewer for such water. His opinion was that since all sewers were constructed not to run more than two-thirds full, they ought to be sealed only so far as the two-thirds go, and if the upper side was left so that the subsoil water could percolate through, it would very gradually but certainly reduce the subsoil water in the land abutting upon the houses, and at the same time the lower part of the sewer being properly constructed,

i. e. water-tight, they would not have the sewage water coming through and saturating the subsoil. Mr. Lemon had said that time ought not to be considered at all in laying down a scheme of sewerage for a district, and that they should deal with the whole district of a Local Board. That was an opinion from which he differed. Let them take Croydon as an example. The whole parish was under the Local Board, and it contains something like 60,000 persons. Now did Mr. Lemon mean that in laying down a system of sewers for the Local Board of Croydon he would make it sufficient for the whole of that parish which he might fairly prophesy would not be built upon for 500 years?

Mr. J. Lemon explained that he meant only for the district to be drained.

Mr. T. Hewson said that after Mr. Lemon's remark there was apparently no difference between himself and Mr. Lemon, who would drain the district *that had to be drained*, and he (Mr. Hewson) would drain the district which the estimated population would require to live upon, but that estimated population must depend upon the number of years for which it was decided to provide. Mr. Lemon had said that he had found as a matter of practice that where he had executed works, after a little while he had to make diverting sewers from the general system into the streams immediately contiguous. He was not surprised at that, because he believed that engineers heretofore had not made that provision in their intercepting sewers which they ought to have done, and consequently after a few years they have and will have to relieve those sewers by discharging into the streams. Mr. Lemon hoped that the Association would not adopt any scheme. He hoped they would. His opinion was that without reason, without proper care and thought, there was a disposition in the minds of municipal engineers and surveyors at all hazards to reduce the difficulties of sewage treatment, that regardless of any reasoning process they run away to the extreme of simply keeping all out of the sewers that was possible. He felt that if the Association had spoken well out on this subject it would have been a great saving to municipal authorities. He thought that a capital point brought out by Mr. Lemon in reference to Croydon, namely, that on Mr. Vawser's principle its sewage is now sufficiently diluted to be admitted into the stream, for he had pointed out in his paper that a much higher degree of dilution than Mr. Vawser supposed was absolutely necessary before the sewage came up to the standard

of purity mentioned in the Royal Commissioners' Report, and so before it could be discharged into a stream. The President had referred to the Thames Conservancy standard, and he thought it would be a capital thing if it could be in some way incorporated in their present proceedings. He said Colonel Jones had mentioned evidence given in a court of inquiry showing that Professor Way was wrong in his conclusions. This evidence was valueless, as it was merely what a witness said he thought, whilst Professor Way's conclusions had never been disputed, and he thought his (Professor Way's) statements had been quoted too often not to have been contradicted if there had been the slightest inaccuracy in them. He had heard it very often said by consulting engineers that a system of sewers should be according to local circumstances, or in other words, that no engineer ought to be so foolish as to say right off what was the correct system. They would all admit that it was what he, if in the same position, would no doubt say. Mr. Pritchard thought that the works ought to be "permanently sufficient," and so far he felt that Mr. Pritchard was with him. Mr. Fox had said that at Barrow by the construction of six miles of duplicate sewers he had been able to save the pumping of 66 per cent. of the rainfall. He put it to Mr. Fox however whether this was not based on the supposition that the storm-waters by the other system could not possibly be disposed of except by pumping, or whether storm-outlets to get rid of the 66 per cent. would not be the answer to the supposed saving?

Mr. Fox explained that the area was below the level of high tide and therefore the storm-water could not be got rid of without pumping it.

Mr. Hewson said that under the circumstances no doubt there was a saving, but he was glad they had had the explanation, else it would have stood on record that in Mr. Fox's experience the single system versus the dual system had brought about this particular result, whereas it was simply brought about by the fact that the town was on a tidal stream. He thought therefore the illustration did not apply, and ought not to have been used in discussing the broad question of the two systems. With regard to Mr. Shone's machine, he thought it was a capital one, and if Mr. Shone would not attempt by way of making his machine answer to go in for the separate system against the combined system he would be more successful.

Mr. R. Vawser, in the course of his reply, remarked that Mr.

Lemon had asked why the natural watercourses, too small to receive storm and surface water, should not be enlarged and improved so that the separate system might be made practicable, but if Mr. Lemon had had a little more experience of the manufacturing districts, he would know that it is no trifling matter to alter a natural watercourse where the water is required for trade purposes. At whose expense must the works be undertaken? If the Corporation of Leeds, for example, desired to improve, deepen, and straighten the Leeds beck, every millowner on the stream would find something to say against it, and he had no doubt the town authorities would very soon find it would cost a great deal more to alter the old watercourse than to make an entirely new one. Mr. Lemon wished to take the opinion of the meeting as to whether he (Mr. Vawser) was right in his contention, "that a perfect system of town drainage must provide for the removal of all liquid refuse, together with the largest rainfall known to have fallen in the district," for his own part he did not wish any one to share his responsibility for the paper. The Association could not be held responsible for it, but judging from the tone of the discussion a great majority of the members concurred with his conclusions, and although Mr. Lemon had advanced certain objections, yet if they carefully considered his words they would find that he did not raise any really valid objection to the principle he had laid down in the paper. Mr. Lemon had told them that only ¼ *inch* of rainfall had been provided for in the London sewers, but he might also have informed them that the Metropolitan Board of Works are now engaged in supplementing their original scheme by a further expenditure of a million and a half of money to provide for the rainfall which the sewers at present could not carry off. Although it has been ascertained that ¼ *inch* of rain or upwards only falls in London on about 25 days in each year, yet it has become necessary to spend one and a half million to supplement the existing works and render them adequate for the purpose intended. If a more liberal provision had been made for rain-water when the sewers were originally designed, a large proportion of the money now about to be expended might probably have been saved. Mr. Lemon had likewise informed them that if the degree of dilution he had suggested were admitted in practice, the sewage of Croydon might be turned into the stream without purification. He was surprised Mr. Lemon had not noticed that he only proposed to turn diluted sewage into the streams during times of rain, which would usually

not exceed 150 days in the course of the year, and probably not more than one hour each day, that was quite different to a continuous flow of sewage night and day all the year round and would certainly be far less objectionable in the streams than the surface water washed from busy streets in slight showers. Mr. Fox had discussed the case of Barrow-in-Furness, but the conditions there were quite abnormal, and did not prove that the principle he had endeavoured to lay down was unsound. He had likewise heard upon the authority of Colonel Jones that it was not practicable to disconnect sewers entirely from houses, and this had been used as an argument against a combined system of sewers, but he (Mr. Vawser) contended that it is practicable, and was being done every day, but the possibility of disconnecting sewers from houses has nothing whatever to do with the duplicate system, because a house in direct communication with a small sewer would suffer precisely the same as if connected with a large sewer. He had suggested that liquid refuse from manufactories might be conducted into sewers in cases where it could not be conveniently disposed of otherwise, but no one would suppose he intended that all waste liquid should be carried off by the sewers. He had been asked specially with reference to liquid refuse from tanneries, but he did not propose to discuss what manufacturing refuse should, and what should not, be turned into a sewer, nor did he desire to enter upon a discussion which might involve questions of trade rights, he simply laid down the broad principle, that in providing for the removal of liquid refuse from a town the local authority ought to provide for the whole of it. Manufacturers are taxed for works of sewerage and town improvement, and in equity can claim that their interests should not be ignored. The owner of 20 cottages rated at 100*l.* per annum can have sewers laid past his premises, and his sewage removed at the expense of the community, and why should a manufacturer on the opposite side of the street, rated perhaps at 1000*l.* per annum, incur a ruinous expense to get rid of his waste liquids, and at the same time be taxed to pay nine-tenths of the expense of dealing with the sewage from the cottages over the way? Unless manufacturers are allowed to derive some advantage from the public sewers, they ought to be exempted from paying for them.

ANNUAL MEETING AT LEEDS,

May 27, 28, and 29, 1880.

THE HIGHWAYS AND LOCOMOTIVES (AMENDMENT) ACT, 1878.

By JOSEPH LOBLEY, Assoc. M. Inst. C.E.

The rapid abolition of turnpike trusts of late years, and consequently the repairs of the roads being defrayed by local taxation, has resulted in a considerable increase to the rates of many districts.

To alleviate in a measure this burden, certain provisions in the Highways and Locomotives (Amendment) Act, 1878, have been framed.

The author proposes to refer to these provisions, more particularly as regards Urban Sanitary Authorities, with the view of eliciting opinions as to their working, and ascertaining if they properly and fairly carry out the intention of the Legislature.

Clause 13 enacts that any road which has since 1870 ceased to be a turnpike road shall be deemed to be a main road, and one half of the expenses incurred from and after September 1878 by the highway authority in the maintenance of such road shall be paid to them by the county authority out of the county rate.

Such payment is to be made on the certificate of the county surveyor that such main road has been maintained to his satisfaction.

Boroughs having a separate court of quarter sessions are exempt from the provisions of this clause.

Repayments of principal moneys borrowed or interest payable thereon are not to be included in the term "expenses."

Clause 14 enacts that the highway areas referred to shall be (1) urban sanitary districts, (2) highway districts, (3) highway parishes not included within any highway district or any urban sanitary district.

The principle involved in these enactments in spreading the

incidence of taxation over larger areas is generally regarded as a proper one; but the actual working of these clauses affords some curious anomalies.

It will be observed that urban sanitary districts are included in the highway areas, with the remarkable exception of those boroughs having a separate court of quarter sessions.

Urban sanitary districts mean generally, as their name implies, towns or town-like populous places, and it may be presumed that by including them in the operation of the Act one of two objects should be attained: either—

That the rates contributed by the urban district to the county rate shall be in excess of the moneys to be paid by the county authority to the urban authority, and that such excess shall therefore go to the relief of other areas outside the limits of the urban district: or—

That the amount to be thus paid by the county shall be in excess of the contribution to the county rate by the urban district, consequently such excess being met by taxation of the areas outside the limits of the urban district.

In other words, either the towns are to assist the country districts in maintaining these main roads, or the rural districts are to assist the urban districts in maintaining the roads in towns.

The principle involved in the latter case has never been acknowledged as a desirable or necessary one to adopt, so that the sole object of including urban districts in the operation of the Act is that the county rate obtained from those districts, being in excess of the moneys required to be repaid to them under Clause 13, shall assist the rural areas.

If it be conceded as a proper principle that towns shall contribute to the expenses of main roads outside their own limits, on what principle of equity are those urban districts having a separate court of quarter sessions made exempt from the operation of the clause?

What relation does the fact of a town possessing quarter sessions bear to the principles involved in taxation for the maintenance of main roads?

It may be urged that it would be inconvenient to levy a county rate in such towns, but that is a difficulty much less than many now existing in the Act, and alluded to further on.

It has been suggested that the principal reason why towns having their separate court of quarter sessions are exempt is, that generally the larger towns have such courts, and that these clauses

could not have been carried through Parliament if the hostility of the representatives of these towns had been aroused.

As matters now stand, the urban districts not having a separate court of quarter sessions have so small a representation in the House of Commons independently of the larger towns and the counties, that it is only by an appeal to the sense of equity and justice of Parliament generally that any alteration can be hoped for.

Clearly if it be right that urban districts should assist the rural districts in the maintenance of main roads, then all urban districts should be included without exception, but if that be not recognized as a correct principle then the simplest alteration would be to exempt all urban sanitary districts from the operation of these clauses.

Each urban district would in that case have its own roads to maintain in such manner as it may determine, without being hampered with the interference of any other authority.

Further, each urban authority could, if it should so determine, execute works of paving, moneys being borrowed for the purpose, repayable with interest within a term of years.

As the clause now stands, this can only be done by the urban authority defraying the entire expense, while the county generally receives the benefit by the annual cost of repairs being materially lessened.

The natural consequence of this is that the urban authority will prefer to spend the borrowed money in paving roads and streets not coming under the term "main roads," in which case any annual saving resulting thereby will be to the advantage of the ratepayers of the urban district.

The author has experience of the working of this sub-section in a Midland manufacturing town. A turnpike trust expiring at the close of 1877 left its roads in a very unsatisfactory condition, and the maintenance thereby devolving upon the urban authority they resolved to repave a certain section in the best modern manner.

The traffic is very great, particularly in coal, and the policy of repaving was considered to be a good one. The expense was to be borrowed for a term of years, repayable in the usual manner.

Tenders for the sets were advertised for and received, when at the last moment the attention of the Council was drawn to Clause 13 in the Act just then passed into law. This resulted in a postponement of the work.

The county officials were then applied to in order to ascertain

whether, in the event of the Council deciding to do the work out of current rates, any question would be raised as to the meaning of the word "maintenance" in Clause 13. To this no official reply has been received, but it has been intimated that the county authority did not see its way to regard the work as "maintenance" but as "new construction," and therefore not within the intention of the clause.

Consequently the work has not been done, and the urban authority has been compelled to execute constantly small repairs, using the old inferior paving sets.

This course is adverse to a good pavement, and must in the end prove to be uneconomical to the ratepayers, both of the borough and the county.

If urban districts are to remain in the Act, this sub-section ought to be modified to the extent of giving the town and county authorities the power, if so agreed between them, of including the annual repayments on loans within the operation of the clause, and also defining the word "maintenance" to mean any work done to the road ordered by the highway authority of the district in which it is situated, and approved by the county authority. Cases of dispute being referred to the Local Government Board for their decision.

The doubts and questions arising out of the meaning of the word "maintenance" are very numerous, some of the various forms of which may be thus enumerated:—

1. Ordinary repairs to the surfaces of paved and macadamized carriageways
2. Extraordinary repairs, such as putting in a good foundation for the pavement or macadam or using new sets.
3. Scavenging or street sweeping.
4. Watering streets.
5. Ordinary repairs to curbs and channels.
6. Extraordinary repairs to same, such as the substitution of new material for old.
7. Ordinary repairs to the side footpaths.
8. New pavements to side footpaths.

It will probably be some time before any clear definition of what should be included and what should be omitted is arrived at between the county authority and the highway authorities, and in all probability different county authorities will arrive at different conclusions.

Clause 15 gives the county authority, on the application of a highway authority, the power of declaring any road to be a main road.

This provision was somewhat curious, as there was nothing in the Act to say definitely that the effect of the declaration was to cause half the expenses to be repayable to the highway authority, in the same manner as disturnpiked roads.

This question has been settled to mean that the declaration shall have such meaning.

In one county in the Midlands with which the author is acquainted, great efforts were made to obtain other roads declared main roads. Each local authority, believing it would be called upon to pay a heavy contribution to the county rate, endeavoured to place itself in the position to receive back as much as possible.

Some of the applications were undoubtedly reasonable, but the result has been curious.

The county authority has uniformly rejected all the applications for the northern half of the county, but granted several in the southern half.

This, of course, simply means that the ratepayers of the northern half will be called upon to contribute to the cost of the maintenance of these roads in the southern half many miles distant, and in which they have no interest whatever.

No reasons have been furnished for the rejection in the one case and the declaration in the other, and consequently no opinion can be properly arrived at by the outside public on the relative merits of the applications.

Clause 16 gives power to reduce main road to status of ordinary highway.

The application to the Local Government Board for the provisional order, and to its subsequent confirmation by Parliament, in all probability protects in the best manner that can be devised the interests of the ratepayers of any highway district.

A similar safeguard is required to be attached to Clause 15.

Clause 18 directs the highway authority to keep, in such form as may be directed by the county authority, a separate account of the expenses of the maintenance of the main roads within their jurisdiction.

This is an important clause, and so long as Clause 13 stands in its present form some such provision is necessary.

The form of account required by the county authorities, as

recommended by the Local Government Board, is no doubt a good and useful one for rural highway districts, where the greater portion of the work done by the authority is done on the main roads.

In the large and populous urban districts coming under the operation of the Act, where the work done on the main roads forms but a small proportion of the total work done by the urban authority, though at the same time in itself very considerable in amount, this form of accounts is altogether insufficient.

Take as an instance a town with a population of 30,000 to 50,000, with its numerous loan accounts for sewerage works, sewage disposal works, markets, street improvements, private street improvements, private drainage, public baths, and so on, and with its numerous current accounts for maintenance of streets, footpaths, sewers, watering and scavenging streets, public lighting, removal of house refuse, fire brigade, and many other accounts for expenses under the Public Health Act, 1875. This town employs, say, sixty men in the above works.

It is clear that such an authority should possess, and as a rule does possess, an excellent and sufficient system of accounts.

For the purposes of this authority, the form of account required to be used for the main roads would be altogether inadequate, as well as cumbrous in the extreme.

The result, therefore, is that the system in use by the urban authority cannot be abandoned, and the separate account in the form required by the county authority has to be kept side by side with the other, involving additional book-keeping and consequently expense to the ratepayers.

It frequently occurs in the author's experience that twenty to thirty different men are employed on the main roads in the course of one week. A portion of each man's time being thus engaged and the remaining portion being occupied on other town work.

The form of account requires each man's name to be entered in the weekly statement, and a similar amount of double book-keeping is requisite for the entry of the other expenses, such as materials, team work, contract work, tradesmen's bills, and incidental expenses.

Before seeking for any remedy for this serious expense, it may be as well to inquire if there be any necessity to retain urban districts in the Act at all. So far it appears to give neither town nor country satisfaction. The country ratepayers labour under the impression that they are called upon to pay for the repairs of main

thoroughfares in busy towns; while on the other hand the town ratepayers believe they will be required to pay in an increased county rate much more than they will receive back from the county authority in half expenses of main roads.

It must be borne in mind that the county rate is generally collected with the poor rate, and requires careful examination to know exactly what it amounts to.

The author urges that the whole machinery of separate accounts, certificates of county surveyor, interference with the work of the urban authority, the distinction between quarter-sessions boroughs and other urban districts, the distinction between expenses on current rates and those on loans, together with most of the applications for roads to be declared main roads, and the host of doubts as to what the word "maintenance" includes, may all be cleared away by omitting urban districts from the operation of these clauses.

There might be a proviso that any urban authority desirous of being included within the operation of the clause should be able to apply to the Local Government Board for a provisional order to that effect, but this should only apply to districts having less than 15,000 inhabitants.

If it be conceded as a recognized principle that towns should contribute to the country roads, then let all urban authorities, without exception, pay a fixed amount in proportion to their respective rateable values to the county funds.

The exemption of quarter-sessions boroughs already excludes most of the large towns, but there are numerous instances of small towns being thus exempt, while neighbouring larger towns are included in the operation of the clauses.

The author has not had the same opportunities of observing the working of the Act in the rural districts, but it cannot be denied that it contains many useful provisions.

The principle of two authorities existing and ruling over the same road, namely the highway authority and the county authority, is one that requires careful attention. Whether it will prove economical is doubtful. The provision that requires the certificate of the county surveyor to be given before the half expenses are repaid by the county authority, may cause the highway authority to expend much more than the circumstances really warrant, and they may thus derive little real benefit by the payment, and in addition will have to contribute their own quota to the general county rate.

The roads themselves would doubtless be improved, but this result might be equally as well obtained by the union of several rural sanitary authorities, so as to enlarge the highway district for the purpose of maintaining the main roads.

Clause 23 enables the highway authority to recover expenses of extraordinary traffic from any person by whose order such traffic has been conducted.

This provision is not free from doubt, and the difficulty of proving to the satisfaction of the court having the cognizance of the case the actual money value of the damage done has been in many cases a great one.

Clause 26 gives the county authority power to make bye-laws for regulating the width and construction of waggon wheels, the use of skid pans, the erection of gates, and the use of bicycles.

This enactment can scarcely yet be appreciated. Some time must necessarily elapse before further provisions can be suggested.

Part 2 of the Act amends the Locomotive Acts of 1861 and 1865.

It may be considered desirable to sanction the extended use of traction engines in country districts, but it is a questionable policy to give increased facilities for their use in busy and populous towns.

There should be a limit to the number of waggons turning the corners of streets, and also some restriction should be placed upon them with regard to the articles conveyed.

The general public safety and convenience should not be sacrificed to enable brewers and others to deliver beer to public-houses in the busiest hours of the day, or to convey other similarly small commodities which could be as readily and probably as economically conveyed in the usual way.

The urban authority should be empowered to institute proceedings against the proper persons for breaches of the law by persons in charge of locomotives.

DISCUSSION.

Mr. J. Allison said he failed to perceive the object of the author of the paper, and contended that Hanley was placed in a favourable position. Clause 15 gave the county authority, on the application of the highway authority, the power of declaring a road to be a main road.

Mr. A. W. Morant (President) explained that in Leeds there were borough quarter sessions, and that the town had nothing to do with the county authority except perhaps for some bridges.

Mr. Chas. Jones said he quite concurred in Mr. Lobley's remarks with respect to Mr. Allison, who was happily exempted and could scarcely sympathize with the position of small towns which had no separate quarter sessions. Such places could not help themselves, but had to go in with the county authority. It must however be remembered that the Act was really an untried one. There was no doubt that time would prove some of the peculiar idiosyncrasies of the Act, and they would have some improvement. There was a certain hardship to those who lived in the outskirts of large towns. They felt it somewhat that the traffic which tore the highways all to pieces in going to the large towns had to be paid for not by the towns, but by the unfortunate urban districts outside of them. He hoped some steps would be taken by which a more equitable arrangement might be made. Another disadvantage was that they were placed so absolutely under the power of the county surveyor's certificate, that being in most cases a verdict from which there was no appeal. He thought the Act was intended to apply only to the road between the kerbs. Perhaps some of the Members present could give an illustration as to what "extraordinary traffic" was taken to mean. He referred to this because last year he nearly lost his certificate in connection with the railway passing through his main road which had cost about 600*l*. a mile. The railway work was unfinished and the bridge being in anything but a creditable state, a question was raised in respect to it. The attention of the clerk of quarter sessions was called to this extraordinary traffic clause, but they had not been able to get a definite expression of his views, this was probably owing to some doubt or difficulty as to a

railway bridge being brought within the extraordinary traffic clause.

Mr. J. Allison said he thought the extraordinary traffic clause was a just one. Four or five years ago, in the town where he was then situated, there was a thoroughly good sound pavement in one of the principal streets. It had stood the test of ordinary wear and tear, for some five or six years, but one night a boiler twenty or thirty tons in weight was carted along by fifteen or eighteen horses, and for an entire length of three-quarters of a mile caused a rut of about 1½ inch. This had to be repaired and levelled, which caused serious inconvenience and expense. The local authorities having ascertained by whom the damage had been done called on and obtained something from them towards the cost of repair and maintenance. Reverting to the 15th Clause, he found that it gave to the county authority, on the application of the highway authority, the power of declaring any road to be a main road. He supposed the highway authority meant the Local Board.

Mr. A. W. Morant agreed with Mr. Allison that the extraordinary traffic clause was a just one. The greatest weight carried over the roads in Leeds had been a boiler of 24 tons on two trucks, that was 24 tons upon eight wheels.

Mr. J. Lemon said his town had quarter sessions and was a county in itself. Nevertheless, he thought that the author had made out a real grievance. It was an unsound system in any case to have a conflict of authority. He knew a case in which two authorities had jurisdiction over roads, the one to make them, and the other to say whether they were properly constructed. He thought that was unsound in principle. The Act now under discussion was introduced by Mr. Sclater-Booth, then President of the Board of Trade. Pressure was brought to bear upon him by the landed interest. It was not so much a question as to Local Boards, but as to whether the farmers should have to pay more than their share for the maintenance of roads where there was heavy traffic, and it was thought that if a contribution was given from the county rate to the highway authority, that would ease their burdens. He thought with the author that the whole system was wrong, and that it would be far better that the district should maintain its own roads, the county authorities maintaining the roads in their own districts. The instances mentioned by the author in his paper were less familiar in the south than in the manufacturing districts. But the question which they raised of repaving the

roads became a very serious one. When a road got into such a state that it was not economical to repair it, they wanted necessarily to pave it, and it was absurd to say they should pay that out of the current rate. They ought to be able to do it just as they did in their own borough, borrowing the money, and spreading the repayments over a number of years, which however they could not do under this Act.

Mr. E. H. ALLIES said that the footpaths as well as the roads were allowed for in his district of West Derby.

Mr. B. C. CROSS said he was glad that had been mentioned, because he was now going to put a footpath on a similar road.

Mr. T. HEWSON said his impression was that the attempt had been to produce an Act of Parliament which should make an inequality into an equitable arrangement. The object of the Act was first to secure for the country a system of national commercial good roads, so that they might be able to start at one end of England and go to the other, finding the main roads equally good throughout. With regard to the cost it seemed to him to be a fair sort of Act. First, it practically said that one-half the cost should be borne by the local authority for its own local use of these roads, and the other half by the county authority for the general public use of them. The line must be drawn somewhere, and it seemed to him that it was a fair and equitable line to draw. The county rate was practically a national one, and was in full force everywhere excepting in places exempted for such purposes as weights and measures and analysts, by Acts of Parliament, passed subsequent to the date of the County Rate Act. Or as by Leeds, Manchester, or any other place having a separate court of quarter sessions where they were freed from the County Rate and the County Road Act. So that if other urban authorities were included in the Locomotives and Highways Act it was for the purpose of receiving back some part of what they paid. Excepting that he objected to having two authorities for one road he had no desire whatever to be relieved from the power to charge the county with half the cost of these turnpike roads. Any road that had been disturnpiked since 1870 was a main road, whether they liked it or not, and it rested with the local authorities whether they would send in application for a portion of the costs. His own inclinations were to fall in with the Act, for he did not believe that it would substantially give any relief—though a particular section might get a special relief—if the magistrates would remember that they were the ministers and not the makers of the law.

Along with the town clerk of Rochdale, he had an interview with the justices at Preston, to whom they represented that the borough did not want to have anything to do with them—the justices,—but would prefer that they might go back to the old system, neither asking the other for anything. Their reply was "the county rate is imposed all over." It was then suggested that the increase of rates should be laid on the particular towns receiving benefit, and so make their county rate a little heavier, but the magistrates replied that they could not do that as they wanted the county rate for all their purposes, and that the incidence of the tax was the same in every town, excepting where the corporation adopted the Weights and Measures Act, or appointed county analysts, &c., and so exempted themselves from county rating under these heads. There was no such means of exemption with regard to roads, except in towns having quarter sessions.

Mr. J. Lobley, in reply, said Mr. Allison was in the happy position of not having to do with those clauses of the Act, inasmuch as Manchester had a separate court of quarter sessions. Highway authorities might make application for roads to be declared main roads, but it rested with the county authority to accede to the request or not as it chose. In Hanley which he represented they expect to pay in round figures about 2000*l.* as addition to the county rate for the main roads of the county and probably might get 1000*l.* back for the half expenses of the main roads within the district, the real question was, why should his town have to pay the extra 1000*l.* for the benefit of the rural roads, while quarter sessions towns were exempt from any such payment. With respect to disturnpiked roads of which he had nine miles, neither the highway authority nor the county authority had any option in the matter, they were "main roads" under the Act and were chargeable accordingly. The Highway authority referred to in these clauses included all Highway districts and urban sanitary districts not having a separate court of quarter sessions. As Mr. Hewson had observed, the county authority had no power to exempt from the county rate any town not having a separate court of quarter sessions, all must as the law stands at present contribute to the expenses of the main roads of the county, that is to certain public highways. Mr. Hewson called the county rate a national rate, but that it certainly was not—it was different in different counties and was not levied for these road expenses in quarter sessions boroughs at all. If these boroughs were not exempt, Mr.

Hewson's remarks on the general equity of the law would be justified. Respecting the footpaths and other doubtful points, Mr. Jones and Mr. Allies seemed to answer each other and only confirmed the words of the paper, that each county would come to different conclusions. From his point of view the more that was rejected by the county authority, providing all in the county are treated in the same manner, the better, as thereby the general county rate would be less. What he contended for was, that the law should be altered so that all urban sanitary districts should be exempted from the main road clauses. There would be no difficulty about the county rate. Towns having a separate police force like Hanley and Rochdale, although not quarter sessions boroughs, did not contribute to the cost of the county police. If that part of the county rate can be thus struck out, so by an alteration in the law could the county main road expenses. The Act was a new one and he thought its burden was only beginning to be felt. He quite agreed with previous speakers in thinking that the extraordinary traffic clause was a useful one. It must be borne in mind that this is applicable to all places inclusive of quarter sessions towns and to all public highways whether main roads or otherwise.

ANNUAL MEETING AT LEEDS,

May 27th, 28th, and 29th, 1880.

THE EFFECT OF SULPHATES ON LIME MORTAR.

By GRAHAM SMITH, Assoc. M. Inst. C.E.

In the year 1870, the author commenced to experiment on the subject of the effect of sulphates on lime mortar, and finding himself at the beginning of 1879 unable to further pursue his investigations he decided to submit a paper on the subject to the Institution of Civil Engineers with a view of enabling others to give the matter their consideration. It afforded him pleasure to find that that body appeared to appreciate his labours inasmuch as it accepted the paper and set it up in type. However as twelve months had elapsed and there was no appearance of the paper being read this session, the author determined to withdraw it, and by the kind courtesy of the Council of this Association he is enabled to bring it before the present meeting.

It was observed by Major, now Major-General, H. Y. D. Scott, C.B., Assoc. Inst. C.E., about twenty-five years ago, that the chemical combination of a small quantity of sulphurous acid gas with limes had the effect of causing them to set, after the manner of cements, without increase in bulk or any considerable elevation of temperature. The union of the gas with the lime was first effected by allowing sulphur fumes to pass into the kilns during the process of calcination; but more regular results have since been obtained by mixing either a soluble sulphate or sulphuric acid with the lime after its having been burnt.

In ordinary mortar the lime before being mixed with the sand is brought to a state of fine division by slaking with water, that is chemically; whereas in General Scott's method mechanical

appliances are resorted to in order to reduce the lime to powder, and water containing finely ground plaster of Paris or other soluble or partially soluble sulphate is then added. When these have been reduced to a creamy paste, the sand is put in along with any further quantity of water necessary to render the mortar when mixed convenient and fit for use. Mortar thus prepared may be used even for plastering purposes shortly after being mixed, as the lime when treated in this manner shows no tendency to slake. The quantity of sulphate required to be added varies with the description of lime and is much governed by the proportion of clay which it contains. Those limes in which only traces of alumina are found, such as the pure chalk limes, require about 7 per cent., whilst blue lias and other hydraulic limes require but 3 or 4 per cent., and with very clayey limes the amount of sulphate may be reduced to 2 per cent. of the bulk of the lime. The principle of General Scott's invention now generally known as the selenitic process is so to combine the lime with water that it shall not burst with the heat, and in fact to arrest the slaking of the lime so that the setting may take place without increase in its volume. By this means the strength of the mortar is increased, and it is rendered quick setting which is a very desirable property under many circumstances. In ordinary building operations however the mortar must not be too quick or it may set before it can be got into the work. A strong but comparatively slow-setting mortar is often therefore to be preferred. The experimental results contained in this paper lead the author to believe that such can be procured by first thoroughly slaking the lime with water, then adding the sulphate to it in that state and afterwards the sand, ashes, pouzzolanas, or other ingredients and mixing the whole in a mill in the usual manner. If this method be pursued and four or five parts of sand be added to one part of slaked lime a slow-setting mortar will be produced, possessing after having set for some time much greater strength than selenitic or Portland cement mortars containing a similarly large proportion of sand. The characteristics of this mortar are therefore entirely different from those of the latter compositions. It would appear that General Scott entirely directed his attention to the neutralization of the slaking properties of quick lime, and not to the employment of a sulphate with slaked lime as here proposed in mixing ordinary mortar.

The adding of plaster of Paris to lime has frequently been said

not to be a new process, inasmuch as it has been used by builders for an indefinite period both with and without lime for plastering purposes, in order to produce a fine quick-setting mortar. The proportion of plaster employed for this purpose however has always been much larger than that adopted by General Scott and proposed to be used by the author. The builder has hitherto mixed a large proportion of plaster with lime on account of its quick-setting properties as a material, and employed the resulting composition for rendering the interior of rooms and similar descriptions of work not exposed to wet or damp; and in such positions were it not for the question of cost many would prefer to use neat plaster of Paris. This mortar prepared with plaster of Paris if subjected to wet or damp would crack and disintegrate, whereas that which the author advocates is suitable for all situations in which it is customary to employ an ordinary mortar. The plaster of Paris, that is sulphate of lime, is added in small quantities because it is the most convenient and economical medium for supplying the requisite chemical constituents. The builder would deem plaster which has been once set as worthless; however it may be inferred that if this substance were reground it would answer in the processes which are now being considered nearly as well as fresh plaster of Paris.

In 1870 the author, then having charge of the testing of the various cements and mortars employed in the works in progress at the Liverpool Docks, availed himself of the facilities thus placed at his disposal, to test the effect of mixing sulphates with slaked lime. The results being somewhat extraordinary it has been thought advisable to bring them in detail before the Institution.*

The lime used in the experiments, unless otherwise pointed out, was Halkin lime, from Flintshire, in North Wales. The limestone from which this lime is derived contains about the same amount of silica and alumina as that from Barrow, and produces an hydraulic lime which however is not equal to Warwickshire blue lias lime in setting or hydraulic properties. The proportions given in the accompanying tables are in all cases by volume; and where the quantity of any ingredient is represented by a fraction, such is of one part and not of the whole quantity of mortar. The quantity of plaster of Paris in all experiments with Halkin lime

* The paper was read as originally written, otherwise it would have been necessary to rewrite it, in order to refer to what has since been published on the subjects of limes and cements.

was a percentage of the quantity of slaked lime. The various descriptions of mortar tested were mixed in mills on the site of works in progress, and by men daily employed upon such duties; and every endeavour was made to ensure that the experiments should be carried out under as nearly as possible similar conditions in each instance.

The first series of experiments was with briquettes having a sectional area of $2\frac{1}{4}$ square inches, such as are usually made for testing Portland cement. These were drawn asunder by means of a Michele lever cement-testing machine, and the results and all particulars are given in Table I. The second series was carried out with pairs of bricks bedded crossways and torn asunder, with the results given in Tables II., III., IV., V., and VI. The bricks were first cut accurately to a width of $4\frac{1}{4}$ inches, then after being thoroughly wetted with water they were bedded transversely one upon the other with a mortar joint $\frac{5}{16}$ inch in thickness. The area of the testing section being $4\frac{1}{4}$ inches by $4\frac{1}{4}$ inches, equal to 18 square inches. On the time arriving for testing stirrups of iron were passed round the ends of the bricks. Two of these were attached by means of a rope to a beam, and on the remaining two was hung a bucket into which dry sand was allowed to run from a hopper. When the bricks parted the door of the hopper was immediately closed and the weight of the bucket and the sand which it contained was taken to be the breaking weight of the specimen. Before proceeding to analyze the results given in the tables it may be well to point out that although the strength of the mortars when only twenty-one and forty-two days old is given the author does not consider it right to test ordinary slaked lime mortar until an age of at least three months has been attained. Attention will be therefore mainly directed to the experiments carried out at eighty-four, and one hundred and sixty-eight days, that is, three and six months respectively. The first two sets of experiments shown in Table I. were carried out by testing ordinary slaked lime mortar, and the remainder by testing the same description of mortar mixed with various proportions of sand and a small percentage of plaster of Paris. It will be seen that the addition of this latter ingredient has a great effect on the strength of the mortar; the average strength of the ordinary mortar being in fact in all instances less than the average strength of the mortar prepared with plaster of Paris. The strength of the former notwithstanding the very much larger proportion of

lime in their composition is in some instances less than half that of the latter.

With a view of ascertaining how far these results would hold good in practice sets of two bricks were bedded transversely and tested in the manner already described. The results in Table II. were obtained with bricks similar, although slightly harder, than ordinary "London stocks"; and those in Table III. with hard fire-bricks, somewhat similar in texture to Staffordshire blue bricks. The mortar was composed of Halkin lime mixed with salt water and sea sand, and the samples were exposed to the atmosphere after being prepared. That to which plaster was added appeared from these results to be considerably stronger than the ordinary mortar, although the excess of strength was not so manifest as in the preceding experiments with briquettes. The tests the results of which are given in Tables IV. and V., were carried out in a similar manner, but the mortar was allowed to set for six days, and was then remixed and made up with salt water. This apparently reduced the strength of each description of mortar, and seemed to have a less damaging effect upon the ordinary mortar than upon the mortar prepared with plaster. The strength of the former however still remained less than that of the latter; and it ought to be noted that where plaster was used the proportions of slaked lime to sand were 3 and 4 parts to 1 part, whereas in the ordinary mortar they were $2\frac{1}{3}$ to 1.

It now remained to be seen how the addition of plaster of Paris would affect mortar intended to be set under water. The experiments the results of which are given in Table VI., were therefore made with ordinary bricks, and the samples immersed in water twenty-four hours after being bedded. These tended to prove that the ultimate strength of the ordinary Halkin mortar was not impaired by immersion in water, but that the strength of the mortar containing a small percentage of plaster was materially reduced.

It would appear from these experiments that by adding plaster of Paris to slaked lime the strength of the mortar will be increased and the cost reduced, consequent on the larger proportion of sand which may be employed; and it may be inferred that experience will demonstrate the advisability of employing plaster of Paris in mortar to be used in ordinary building operations, but that it will not be found advisable to add it to slaked lime mortars intended for hydraulic purposes.

In further treating the subject of the effect of sulphates on lime mortars it will be well to consider some of the results of experiments with selenitic and other descriptions of mortar which have been made at different times by various authorities. The experiments given in Table VII. were carried out by Mr. Kirkaldy, with briquettes having a sectional area of 2½ inches by 2 inches, equal to 5 square inches in area. The actual breaking weights are reduced in the last column to the equivalent weight required to break a testing section of 2¼ square inches. If these at fifty-six days be compared with those at forty-two days in Table I., it will be seen that there is a considerable amount of strength in favour of the slaked lime process. Burham lime is undoubtedly richer than Halkin lime, but this fact ought to tell in its favour as it must be borne in mind that a larger portion of sand may be mixed with a rich lime than with a hydraulic lime. It should likewise be noted that the Burham lime was apparently measured in its ground state, whereas in all the slaked lime experiments the lime was measured after being slaked. As Burham lime about doubles in volume in the process of slaking, the proportions 1 to 6 and 1 to 5 in the tests with selenitic mortar should be considered as 1 to 3 in estimating the merits of the mortars. The results in Table VIII. were likewise arrived at by Mr. Kirkaldy by tearing asunder two "stock" bricks bedded transversely with a mortar joint 18½ square inches after being set fifty-six days. These when compared with Table II. show a decided margin of strength in favour of the slaked lime process. They somewhat exceed the results given in Table III., but these were obtained with hard firebricks, and were a test of the adhesive qualities rather than of the strength of the mortar. The experiments of Mr. A. W. Colling, clerk of works to the new law courts, in 1871, the results of which are given in Table IX., were made with bricks 4½ inches in width, which when bedded transversely gave a mortar joint of 20¼ square inches area. These were tested at twenty-eight days, and if the results are reduced by 10 per cent. on account of the increased area of testing section, they do not show any great excess of strength over the results at twenty-one days in Tables II. and III., notwithstanding that the slaked lime mortar had not had time to set properly. Table X. comprises results obtained by tearing asunder bricks bedded in a similar manner by Mr. Hartley, late of the Royal Engineers, and tested by Mr. Gilbert Redgrave, Assoc. Inst. C.E. If these at twenty-eight and thirty-five days be compared

with those at twenty-one days in Tables II. and III., it will be seen that they exceed the results at twenty-one and forty-two days, but as already pointed out the selenitic mortar had a larger portion of lime in its composition, and comparisons ought not to be instituted with slaked lime mortar of this age.

Experiments with selenitic mortar are however permissible at an early age as that mortar sets quickly,* and attains the consistency of wax in a few hours. It may be well therefore to compare the strength of this mortar, given in Table IX., with that given in Table X., as the mortar apparently was made with the same quality and description of lime and was tested under similar circumstances. Mr. Redgrave found the strength to vary from 399 to 438 lbs., whereas Mr. Colling found its average strength to vary from 196 to 284 lbs. The experiments in Table XI. were likewise due to Messrs. Hartley and Redgrave, and the results were derived from testing briquettes having a sectional area of 2¼ square inches. If these be compared with those given in Table I., it will be found that when the mortars have attained the age of six months any advantage in strength is decidedly in favour of the slaked lime mortar prepared with plaster, and that even at three months it has nearly double the strength of the selenitic mortar made with the same kind of lime. At six months the same remark will apply to the Portland cement mortar. Whilst drawing attention to this point the author does not wish it to be understood that he considers any description of lime mortar can equal in strength or setting properties neat Portland cement, or Portland cement mortar, in which a small proportion of sand is used. However when a large admixture of sand is made slaked lime mortar prepared with plaster appears to be decidedly stronger than Portland cement mortar containing a similarly large proportion of sand. Even ordinary Halkin lime mortar, when mixed in the proportions of 2⅓ to 1, at the age of six months is about equal in strength to Portland cement mortar mixed in the proportions of 4 to 1.

Tables XII. and XIII. comprise results abstracted from the Paper by Mr. John Grant, M. Inst. C.E., on the strength of Portland cement,† read before this Institution in 1865. The experiments from which Table XII. is taken were made with Portland cement weighing 112 lbs. to the imperial bushel, gauged neat

* *Vide* 'Minutes of Proceedings Inst. C.E.,' vol. xxv. pp. 87 and 88.
† Ibid.

and with different proportions of various kinds of sand, showing the breaking weight on a sectional area of 2¼ square inches; and the results in Table XIII. were carried out under similar circumstances, but with different proportions of various kinds of sand. If these experiments at three and six months be compared with the results obtained with ordinary mortar in Table I., it will be seen that when the proportions of sand to cement are 3 to 1 the strength of the cement mortar somewhat exceeds that of the lime mortar. When the cement mortar is mixed in the proportion of 4 to 1 its strength is if anything slightly less than that of the lime mortar, and when the sand and cement are in the proportions of 5 to 1 the strength of the lime mortar considerably exceeds that of the cement mortar. Now if the results obtained with mortar prepared with plaster of Paris and slaked lime given in Table I., be compared with these experiments with Portland cement, it will be found that they considerably exceed the strength of the latter, even when the cement mortar is mixed in the proportions of 3 to 1 and the lime mortar in the proportions of 4 to 1 and 5 to 1.

Table XIV. contains the results of experiments carried out by the late Lieutenant W. Innes, R.E., Assoc. Inst. C.E.,* with cement supplied to the War Department of a high average weight and tensile strength. Again referring to Table I., it will be seen that the strength of mortar prepared with plaster in the proportions of 5 to 1 exceeds that of cement mortar mixed in the proportions of 3 to 1. When the cement was passed through a sieve with 1296 meshes per square inch before being mixed with the sand, its strength closely approximated to that of the lime mortar with plaster; but when the cement was passed through a sieve with 2500 meshes per square inch the mortar made with it mixed in the proportions 3 to 1, exceeded in strength the plaster mortar mixed in whatever proportions.

It may on the whole be taken for granted that mortar composed of 4 or 5 parts of sand to 1 part of slaked lime can be made possessing greater strength than Portland cement mortar mixed in similar proportions. The economy to be effected is evident when it is considered that the normal price of Portland cement is not less than 2*s*. per bushel, whilst a bushel of slaked lime does not cost one-third of that amount.

The broken portions of the briquettes with which the first series of experiments was made have been exposed to the weather since

* *Vide* 'Minutes of Proceedings Inst. C.E.,' vol. xxxii. p. 322.

1871; those mixed in the proportions of 5 parts of sand to 1 part of slaked lime give evidence of being sound material, and of having stood equally as well as those mixed without plaster in the proportions of 1 to $2\frac{1}{3}$.

In making mortar the proportions of sand, ashes, and other ingredients, which ought to be adopted depend entirely upon the nature of the lime, for instance no engineer would put as much sand with blue lias as with greystone lime. In the process now proposed similar laws will hold good, but as a general rule double the quantity of sand may be used when plaster is added, that would be considered proper with any particular lime under ordinary circumstances.

Some of the comparisons are hardly admissible, the experiments having been carried out by different authorities with different limes and cements, and under different circumstances. Although they may be insufficiently exact when looked at from an experimental science point of view, the author trusts that they will be considered adequate for a preliminary inquiry concerning the nature and working of a material used in construction. His only regret is that he is not in a position to lay before the Institution experimental results directly bearing on all the questions raised. He has carried out many experiments with blue lias, greystone, and other limes with a view of ascertaining if these limes would behave in a similar manner to Halkin lime when prepared with a small percentage of plaster. The results of these experiments are not brought forward as many of the batches of samples were accidentally destroyed, and the remainder not being sufficiently numerous to allow of definite conclusions being formed, were tested in a crude manner with a home-made steelyard. In conclusion it may be stated that nearly eight hundred experiments with bricks and briquettes carried out in various manners tend to endorse the general results accompanying this communication and the opinions advanced, which are briefly: that the ultimate strength of all lime mortars will be much increased by the addition of a small percentage of plaster of Paris, and that when mixed in the manner described they will apparently at first possess similar properties to ordinary mortar made with the same kind of lime in the manner as at present practised.

TABLE I.—EXPERIMENTS WITH HALKIN LIME MORTAR, mixed with sand and ashes, ground thirty minutes in a mortar mill.

Description of Mortar.	Proportions. Lime.	Sand.	Ashes.	Plaster of Paris.	Mixed with Salt or Fresh Water.	Number of lbs. required to break by tension briquettes with a testing section $1\frac{1}{2}'' \times 1\frac{1}{2}''$ equal to $2\frac{1}{4}$ square inches in area. 21 days.		42 days.		84 days.		168 days.	
				Per cent.									
Ordinary mortar	1	2	½	..	Fresh	42 65 73	60	145 128 117	130	150 160 150	153	225 253 266	248
Ditto ditto	1	2	½	..	Salt	60½ 40½ 39	47	74 61 87	74	120 149 133	134	178 119 144	147
Ditto ditto (with plaster added) ..	1	2	..	4½	Fresh	118 84 93	98	112 199 111½	141	330 360 330	340	390 351 385	375
Ditto ditto	1	2	..	4½	Salt	74 73½ 59	69	206 135 208	183	297 200 200	232	380 395 ..	387
Ditto ditto	1	3	..	4½	Fresh	121 123 ..	122	162 168 138	156	313 328 278	306	375 358 460	398
Ditto ditto	1	3	..	4½	Salt	124 145 152	140	345 130 155	210	402 325 402	376	..	
Ditto ditto	1	4	..	4½	Fresh	86 102 102	97	114 137 211	154	320 272 305	299	405 435 425	422
Ditto ditto	1	4	..	4½	Salt	100*		190*		400*			
Ditto ditto	1	5	..	4½	Fresh	71 39 84	65	198 189 ..	193	228 310 220	253	360	
Ditto ditto	1	5	..	4½	Salt	77½ 76 55½	70	225 246 224	232	310 340 285	312	320	

* With the exception of three briquettes the whole were accidentally destroyed, one experiment alone could therefore be made at each period.

TABLE II.—EXPERIMENTS WITH HALKIN LIME MORTAR, mixed with salt water, sea sand, and ashes, ground thirty minutes in a mortar mill. The samples were exposed to the atmosphere after being prepared.

Description of Mortar.	Proportions.				Number of lbs. required to tear asunder two ordinary soft bricks bedded crossways with a mortar joint $4\frac{1}{2}'' \times 4\frac{1}{2}''$ equal to 18 square inches in area.			
	Lime.	Sand.	Ashes.	Plaster of Paris.	21 days.	42 days.	84 days.	168 days.
				Per cent.				
Ordinary mortar	1	2	$\frac{1}{3}$	..	102 142 160 } 135	182 244 209 } 212	503 302 296 } 367	497 637 353 } 496
Ditto ditto (with plaster added) ..	1	4	..	$4\frac{1}{2}$	198 208 176 } 194	447 553 434 } 478	520 466 575 } 520	576 805 728 } 703
Ditto ditto	1	3	1	$4\frac{1}{2}$	302 169 198 } 223	433 416 336 } 395	445 437 486 } 456	518 314 468 } 433

TABLE III.—Experiments carried out in a similar manner to those in Table II., but with hard fire-bricks somewhat of the texture of Staffordshire blue bricks in place of the ordinary soft bricks.

Description of Mortar.	Proportions.				Number of lbs. required to tear asunder two ordinary soft bricks bedded crossways with a mortar joint $4\frac{1}{2}'' \times 4\frac{1}{2}''$ equal to 18 square inches in area.			
	Lime.	Sand.	Ashes.	Plaster of Paris.	21 days.	42 days.	84 days.	168 days.
				Per cent.				
Ordinary mortar	1	2	$\frac{1}{3}$	..	213 158 200 } 190	230 199 238 } 222	324 331 308 } 321	417 408 474 } 433
Ditto ditto (with plaster added) ..	1	4	..	$4\frac{1}{2}$	225 215 238 } 226	240 289 327 } 285	359 372 331 } 354	454 364 508 } 442
Ditto ditto	1	3	1	$4\frac{1}{2}$	209 244 186 } 213	269 357 337 } 321	511 405 471 } 462	617 625 678 } 640

TABLE IV.—EXPERIMENTS WITH HALKIN LIME MORTAR, mixed with salt water, sea sand, and ashes, ground thirty minutes in a mortar mill, and afterwards remixed by hand six days after being first made. The samples were exposed to the atmosphere after being prepared.

Description of Mortar.	Proportions.				Number of lbs. required to tear asunder two ordinary soft bricks bedded crossways with a mortar joint 4¼″ × 4¼″ equal to 18 square inches in area.			
	Lime.	Sand.	Ashes.	Plaster of Paris.	21 days.	42 days.	84 days.	168 days.
				Per cent.				
Ordinary mortar	1	2	1/3	..	159 189 200 176 } 181	157 142 250 254 } 201	245 394 308 244 } 298	311 535 440 441 } 432
Ditto ditto (with plaster added) ..	1	4	..	4½	197 187 227 237 } 212	324 352 192 311 } 295	235 209 554 207 } 301	261 420 372 366 } 355
Ditto ditto	1	3	1	4½	262 211 277 237 } 247	295 414 327 300 } 334	246 205 435 560 } 361	355 550 459 397 } 440

TABLE V.—Experiments carried out in a similar manner to those in Table IV., but with hard fire-bricks somewhat of the texture of Staffordshire blue bricks, in place of the ordinary soft bricks.

Description of Mortar.	Proportions.				Number of lbs. required to tear asunder two ordinary soft bricks bedded crossways with a mortar joint 4¼″ × 4¼″ equal to 18 square inches in area.			
	Lime.	Sand.	Ashes.	Plaster of Paris.	21 days.	42 days.	84 days.	168 days.
				Per cent.				
Ordinary mortar	1	2	1/3	..	191 225 139 172 } 182	219 170 178 242 } 202	272 244 302 254 } 268	380 373 375 329 } 364
Ditto ditto (with plaster added) ..	1	4	..	4½	228 221 185 228 } 215	277 253 294 265 } 272	207 385 356 225 } 293	421 344 367 338 } 367
Ditto ditto	1	3	1	4½	158 235 203 201 } 199	242 305 211 286 } 261	399 459 399 390 } 412	368 368 445 389 } 392

TABLE VI.—EXPERIMENTS WITH HALKIN LIME MORTAR, mixed with salt water, sea sand, and ashes, ground thirty minutes in a mortar mill. The samples were immersed in water twenty-four hours after being prepared.

Description of Mortar.	Proportions.				Number of lbs. required to tear asunder two ordinary soft bricks bedded crossways with a mortar joint 4¼″ × 4¼″ equal to 18 square inches in area.		
	Lime.	Sand.	Ashes.	Plaster of Paris.	21 days.	42 days.	84 days.
				Per cent.			
Ordinary mortar	1	2	½	..	15, 49, 27½, 13½ } 26	144, 111, 162, 137 } 138	310, 364, 441, 438 } 388
Ditto ditto (with plaster added)	1	4	..	4½	13½, 8½, 27, 9 } 14	134, 60, 94, 18 } 76	274, 295, 246, 187 } 250
Ditto ditto ditto..	1	3	1	4½	12½, 9½, 11, 8½ } 10	159, 109, 25, 148 } 110	148, 304, 148, 139 } 185
Ditto ditto ditto..	1	3	..	4½	39, 51½, 46½, 45 } 45	173, 80, 148, 105 } 126	192, 207, 179, 304 } 220
Ditto ditto ditto..	1	2	..	4½	79, 41, 33, 37 } 47	102, 91, 80, 60 } 83	245, 121, 203, 305 } 218

TABLE VII.—EXPERIMENTS CARRIED OUT BY MR. KIRKALDY, in 1872, for the Patent Selenitic Mortar Company, with Burham Lime Mortar mixed with sand.

Description of Mortar.	Age in Days.	Proportions.		Number of lbs. required to break by tension briquettes with a testing section 2½″ × 2″ equal to 5 square inches in area.	
		Lime.	Sand.	5 square inches section.	Reduced to 2¼ sq. inches section.
Ordinary mortar	56	1	3	169, 159, 123 } 150	67
Ditto ditto	,,	1	2	129, 116, 104 } 116	52
Ditto ditto	,,	1	4	98, 94, 71 } 88	40
Selenitic mortar	,,	1	4	392, 383, 305 } 360	162
Ditto ditto	,,	1	6	380, 358, 342 } 360	162
Ditto ditto	,,	1	5	289, 209, 202 } 233	105

TABLE VIII.—EXPERIMENTS CARRIED OUT BY MR. KIRKALDY, in 1872, for the Patent Selenitic Mortar Company, with Burham lime mortar mixed with sand. In the last column is given the number of lbs. required to tear asunder two ordinary "stock" bricks bedded crossways with a mortar joint 4·3" × 4·3" equal to 18½ square inches in area.

Description of Mortar.	Age in days.	Proportions.		Breaking Weight in lbs.	
		Lime.	Sand.		
Ordinary mortar	56	1	3	207 148 144	166
Ditto ditto	"	1	2	157 125 121	134
Ditto ditto	"	1	4	145 132 104	127
Selenitic mortar	"	1	4	380 357 322	353
Ditto ditto	"	1	6	377 323 287	329
Ditto ditto	"	1	5	326 255 149	243

TABLE IX.—EXPERIMENTS CARRIED OUT BY MR. A. W. COLLING, Clerk of Works to the New Law Courts, in 1871, with various descriptions of mortar mixed in a mortar mill. In the last column is given the number of lbs. required to tear asunder two bricks bedded crossways with a mortar joint 4½" × 4½" equal to 20¼ square inches in area.

Description of Mortar.	Age in days.	Proportions.		Breaking Weight in lbs.	
		Lime.	Sand.		
Barrow lime ordinary mortar ..	28	1	3	135 105 136	125
Barrow lime selenitic mortar ..	"	1	5	354 269 228	284
Ditto ditto ..	"	1	6	193 228 167	196
Greystone lime ordinary mortar ..	"	1	3	100 100 137	112
Ditto selenitic mortar ..	"	1	6	211 209 209	210

TABLE X.—EXPERIMENTS CARRIED OUT BY MR. GILBERT REDGRAVE, Assoc. Inst. C.E. with various descriptions of Mortar, the samples having been prepared by Mr. Hartley, late of the Royal Engineers. In the last four columns are given the number of lbs. required to tear asunder two bricks bedded crossways with a mortar joint 20 square inches in area, the mortar being mixed with sand.

Description of Mortar.	Age in days.	Breaking weight in lbs.			
		1 to 3.	1 to 4.	1 to 5.	1 to 6.
Portland cement mortar ..	28	..	463	325	313
Barrow lime selenitic mortar ..	"	541	418	399	399
Burham lime ditto ..	"	484	454	368	408
Portland cement mortar	35	..	520	433	309
Barrow lime selenitic mortar	"	435	539	438	430
Burham lime ditto	"	424	430	490	556

TABLE XI.—EXPERIMENTS CARRIED OUT BY THE SAME AUTHORITIES AS THOSE IN TABLE X. In the last four columns are given the number of lbs. required to break by tension briquettes with a testing section 1½″ × 1½″ equal to 2¼ square inches in area.

Description of Mortar.	Age in days.	Breaking weight in lbs.			
		1 to 3.	1 to 4.	1 to 5.	1 to 6.
Portland cement mortar ..	167	..	206	149	114
Burham lime selenitic mortar	161	255	..	..	250
Ditto ditto	165	..	..	170	210
Ditto ditto	234	..	340	..	..
Halkin lime ditto*	76	129	197	99	111

* This result is authenticated by the Patent Selenitic Mortar Company; it is not stated by whom he experiments were carried out.

TABLE XII.—ABSTRACT FROM MR. GRANT'S TABLE XVI.,* on the results of 370 experiments with Portland Cement, weighing 112 lbs. to the imperial bushel, gauged neat, and with different proportions of various kinds of sand, showing the number of lbs. required to break by tension briquettes with a testing section $1\frac{1}{2}'' \times 1\frac{1}{2}''$ equal to $2\frac{1}{4}$ square inches in area, in 1861 and 1862.

Age.	Neat Cement.	The same Cement mixed with Thames Sand from Deptford Works.		
		1 to 3.	1 to 4.	1 to 5.
3 months	..	..	..	116·0
6 "	960·8	308·1	149·0	122·5

TABLE XIII.—ABSTRACT FROM MR. GRANT'S TABLE XVII.,* on the result of 960 experiments with Portland Cement weighing 112 lbs. to the Imperial bushel, gauged neat, and with different proportions of various kinds of sand, showing the number of lbs. required to break by tension briquettes with a testing section $1\frac{1}{2}'' \times 1\frac{1}{2}''$ equal to $2\frac{1}{4}$ square inches in area, in 1862 and 1863.

Age.	Neat Cement.	Clean Thames Sand.			Clean Pit Sand.			Loamy Pit Sand.		
		1 to 3.	1 to 4.	1 to 5.	1 to 3.	1 to 4.	1 to 5.	1 to 3.	1 to 4.	1 to 5
3 months	877·9	135·5	109·0	88·5	305·3	153·0	123·5	149·0	118·5	78·5
6 "	978·7	232·4	157·0	95·5	304·0	275·6	218·8	274·2	225·5	141·0

TABLE XIV.—EXPERIMENTS CARRIED OUT BY THE LATE LIEUT. W. INNES, R.E., Assoc. Inst. C.E.,† with various descriptions of Portland Cement Mortar, showing the number of lbs. required to break by tension briquettes with a testing section $1\frac{1}{2}'' \times 1\frac{1}{2}''$ equal to $2\frac{1}{4}$ square inches in area. Each result is the mean of not less than 10 experiments.

Description of Portland Cement.	Weight per Bushel.	Proportions.		Three Months.		Six Months.	
		Cement.	Sand.	$2\frac{1}{4}$ Sq. Inches.	1 Square Inch.	$2\frac{1}{4}$ Sq. Inches.	1 Square Inch.
	lbs.						
Cement as received from manufacturers	116	Neat 1	Neat 3	1,134 232	504 103	1,186 340	527 151
The same cement passed through a sieve with 1296 meshes per square inch, which rejected 20 per cent. by weight ..	162	Neat 1	Neat 3	1,028 322	457 143	1,107 389	492 173
The same cement passed through a sieve with 2500 meshes per square inch, which rejected 30 per cent. by weight ..	199	Neat 1	Neat 3	1,010 389	449 173	1,093 513	486 228

* *Vide* 'Minutes of Proceedings Inst. C.E.,' vol. xxv. p. 87.
† *Ibid.*, vol. xxxii. p. 322.

DISCUSSION.

Mr. J. Allison, having called attention to the statement in the paper "that mortar composed of four or five parts of sand to one of slaked lime could be made possessing greater strength than Portland cement mortar mixed in similar proportions," said that he had not tested the matter, and was not familiar with the experiments upon which this statement was founded, but he would say that the Association was greatly indebted to Mr. Graham Smith for the paper he had prepared, and although it appeared to him as an entirely new theory, he thought the statements and remarks of the author would be an incentive to the Members of the Association to have the question thoroughly tested.

Mr. R. Vawser said he would have been glad had there been time and opportunity to discuss this interesting paper at length, but the number of complicated tables which it necessarily contained made this scarcely practicable at so late an hour. There were one or two points, however, upon which it struck him as desirable that the author should give them further information. Some of the samples had been mixed with sea water, and he would like to know whether the use of sea water would make any difference as compared with experiments in which fresh water was used. It appeared to him inconsistent, if not incredible, that by adding a small undefined quantity of plaster of Paris, ordinary lime could be made superior to cement. He was rather inclined to think that the author was under a misapprehension. Another question which occurred to him was to ask what would be the effect of moisture or dampness upon mortar composed in part of plaster of Paris? also, what was the effect of time upon mortar composed of lime mixed with plaster of Paris?

Mr. J. Lemon remarked that they had all doubtless read the work of Mr. Grant, who made a large number of experiments, and found that there was practically no difference between using salt water and fresh water in mixing cement mortar. He had had no experience with lime mixed with salt water.

Mr. W. A. Richardson said it was important to consider whether mortar formed of a certain proportion of plaster of Paris would

resist water, as would be required for the purpose of a reservoir. Turning to the experiments described in Table I., he was struck with the disproportion of the strain at which the same materials broke, making it extremely difficult to establish any analogy between the different results.

Mr. J. LOBLEY asked what was the difference, if any, between the sulphates in lime mortar and the selenitic lime patented by General Scott. He had used the latter to a considerable extent for sewage and other works. It certainly enabled him to use more sand, and made an excellent hydraulic mortar.

Mr. GRAHAM SMITH, in reply, said that he had hoped to complete his investigations on the subject of his paper before making them public, but for some years past he had had to conduct his experiments as a private individual, and had not had an official department at his back to defray expenses and give him the control or use of testing machinery. At one time he had considerable facilities for carrying on experiments, and the results given in the paper would show that he had taken advantage of his opportunities. Experiments with mortar required very great care from the time of mixing to the time of testing, in order to ensure accurate results. He said that, having been engaged on professional work in various parts of the country, he had necessarily to leave his bricks and samples in the charge of hotel proprietors, servants, or any other persons who would look after them. The consequence was that many of the samples were either lost or destroyed, and the remainder were not sufficient to enable the author to pin his opinion to the proportions of sulphate to be employed, or the exact results to be expected from the various descriptions of lime. He had however by his experiments satisfied himself that he was justified in expressing the opinions contained in the paper, and was of opinion that if the proper proportions of sulphate were employed, the results with most limes would be as satisfactory as he had found them to be with the Halkin lime experiments described in the paper. With regard to Mr. Vawser's remark that he was under a misapprehension, he would not say that he was not so, but he would say that he had taken every means in his power to satisfy himself before making the matter public. However he only brought the subject forward as a preliminary inquiry, hoping that some one would proceed with the investigation which he had not the time or the means to pursue further. With regard to the effect of dampness upon the mortar to which sulphate had been added, from his

experience he could say that if the sulphate was mixed in proper proportions that damp would have no effect whatever, as evidenced by the samples which he had laid before the meeting, and which had been exposed in Liverpool from the time of their being mixed in 1871. With reference to Mr. Richardson's question as to whether the mortar would be suitable for the construction of a reservoir, he said he would not recommend that the mortar should be used in a work of magnitude until independent authorities had experimented upon it. The experiments in Table I., carried out at 84 and 168 days, he submitted, were as uniform as could be expected from a material like mortar, and the experiments at earlier periods he had already pointed out in his paper should not be considered, as it was not fair to test slaked-lime mortars until they had set three or six months. It must not be understood that he was competing with Portland cement or selenitic mortars. Pure Portland cement would far surpass in strength slaked lime to which sulphate was added, but he was satisfied that the latter with a large admixture of sand would surpass in strength the former with a similarly large proportion of sand. He had explained this in the paper, likewise the difference between the slaked lime process and the selenitic process. In reply to Mr. Lemon, he said he had made many experiments with mortar mixed with salt water, and on comparing them with similar experiments with mortar mixed with fresh water, he had come to the conclusion that the strength of the mortar was certainly not reduced by the use of salt water. The salt water however caused it to nitrate, or saltpetre as it was commonly termed, and so disfigured the work, it should consequently not be used for works of any architectural pretensions or in the building of dwelling-houses. In conclusion he would only add that professional instincts alone had prompted him to carry out his investigations on the effect of sulphates on slaked lime mortar, and bring the results before the public through the instrumentality of the Association.

ANNUAL MEETING AT LEEDS,

May 27, 28, and 29, 1880.

SEWER VENTILATION.

By WILLIAM BATTEN, Assoc. M. Inst. C.E.

It frequently happens that, with many advantages which arise from the application of scientific discoveries in matters especially relating to public health, and sanitary questions in general, unforeseen difficulties occur which to a large extent invalidate our efforts, and this has been very evident in our attempts to deal with the disposal of the liquid refuse of our houses by the water-carriage or sewer system.

In most of our large towns the water-closet is rapidly replacing the old cesspool, privy, or midden. In London water-closets are compulsory. Consequent on this the sewers are constantly being called on to perform duties which in their original construction they were never intended for. The result can plainly be seen.

The refuse from the house-closet and drain is not carried away with sufficient rapidity. It enters the sewers, and becoming stagnant, soon undergoes chemical decomposition, producing what are familiarly known as sewer gases, that act most prejudicially to health. Even in the metropolis, where a gigantic scheme of drainage has been carried out at an expense of several millions sterling, this evil of sewer exhalations is universal, and constantly on the increase, just in proportion as the erection of new buildings increases the pressure on the powers of the existing sewers, already too small to carry off the refuse cast into them. It is not only in London that the evil exists, but in every large town in the kingdom into which the water-closet system has been introduced the danger to health is constantly accumulating. The question thus had become one of national importance. Sewer gas emanation into houses, and a satisfactory state of health in a district suffering therefrom, are incompatible conditions; consequently it has been found that wherever

such a state of things exists the general health of the district suffers, diseases of a typhoid and other dangerous type are propagated, and the death rate enormously increased. A perusal of the reports of the Registrar-General, and of the various medical officers of Local Boards, &c., throughout the kingdom, amply confirms the truth of these remarks.

Sanitary engineers have attempted by an almost endless series of inventions to keep these sewer gases out of our houses. Traps, inside and outside, disinfectants, and almost every variety of modification of the usual system of house drainage have been tried. The results have been of little practical value, for as long as there are main sewers in the streets, there will be sewage gases formed in them which, despite all our endeavours, will find their way into the adjacent houses. The sewers themselves must be dealt with if it is wished to mitigate the evil.

Numerous plans of sewer ventilation have been suggested so as to remove the offensive gases, directly. Ingenious mechanical plans have been devised to withdraw the gases, such as fans driven by steam or other power, utilizing the draught of factory or house chimneys, and many other contrivances which cannot here be described.

The only practical plan seems to be that of allowing the gases to rise from the sewers to the middle of the roadway so as to escape by means of grids into the open air, rising naturally, or at least of their own accord, into the atmosphere.

But the grids are constantly being choked up by the solid refuse present on the roads, and then they cease to become ventilators. This solid refuse is, perhaps, on the first shower of rain washed into the sewers, and there its animal and vegetable matters become decomposed, and add to the already existing evils of the decomposition of the house sewage.

The object of the invention which the author now brings forward is to remedy these evils. The ventilator and manhole covers are so constructed that while admitting the ingress of water and road waste, the solid portion of these is retained, and so prevented from entering the sewer. The whole of the solid road refuse is kept back by the external chambers which receive it. The construction is such that while the ingress of water and waste is going on, provision is made for the egress of the sewer gases; and thus a constant ventilation is carried on without a chance of being stopped. The solid refuse which enters the chambers is easily removed in a

few minutes by simply inserting a piece of bent flat iron into the dirt-receiving boxes, or external chambers.

By withdrawing a bolt, which temporarily fixes the cover of the ventilator, free access is given to the shaft for the introduction of a lamp, or for the purpose of flushing the sewers.

The invention has advantages over most other ventilators and manhole covers inasmuch as a thorough ventilation of the sewers is secured. Free access is given to the sewer for flushing and other purposes; and as the entry of solid matter into the sewers is entirely prevented, the decomposition of such matters in the sewers is rendered impossible, and the stoppage of the sewers consequently avoided.

DISCUSSION.

Mr. C. Jones remarked that the system recommended by the author of the paper appeared to be a simple method of getting over an admitted difficulty. It was objectionable to find the sewer grids stopped up where the gas ought to be escaping.

Mr. A. W. Morant (President) remarked that the ventilation by gullies was introduced for the sake of avoiding expense in digging shafts. The system recommended by Mr. Batten did not appear to differ materially from that used in Leeds, where there were as many ventilators in the centre of the road as could be arranged. These ventilators were in two compartments, and the openings had to be occasionally cleaned out.

Mr. A. M. Fowler said he looked upon this invention as a rather complicated affair. He had not seen anything better than Sir John Hawkshaw's arrangement at Cardiff, where he was engaged on the sewers in 1858. The sewers there were laid out by Sir John, who simply had openings in the centre of the road, with shafts to the top of the sewer, these had small iron coverings with slots, placed at intervals of 100 or 150 yards apart. Underneath these slots cans were placed to catch the dirt, but it was so small in quantity that, in his opinion, the cans were of little practical use and should therefore be taken out. In all these shafts very little dirt went through the holes, indeed in large sewers the sewerage washed it away. It was only in small sewers, say up to 16 inches by 12 inches, with little or no flow in them, that catch chambers were required. It was a more serious matter

to have the tops of the gullies open, so that macadamized road matter in suspension flowed in and settled.

Mr. A. W. Morant said that in the country where the roads were repaired with gravel, he believed that a great deal of harm was done by stones or hard matter getting into the small sewers and accumulating there in a pyramid, which did not get washed away. The disadvantage of the system brought before them by Mr. Batten seemed to be that it would require attention almost daily.

Mr. J. Allison said he quite appreciated the remarks of the President. With respect to the use of boxes, as used in Leeds, when they were full they appeared so on the surface, and that called the attention of the workmen or authorities to them to have them emptied, but according to this new principle, they had eight small chambers, and had to go digging about with a sort of huge toothpick to get them emptied out. So long as the débris collected in the chamber was within an inch or so of the surface, no one would pay attention to them. According to the Leeds system, they had had only to take up one half of the hinged cover, lift the pan, and tip its contents into a cart or barrow, the whole thing being completed in a few minutes. Splitting the openings up into so many chambers, as proposed, rendered it too complicated.

Mr. B. C. Cross said he did not agree with Mr. Fowler that the most simple plan was always the best. He remembered going into a manhole in his own town where his men had omitted to put some protection, and there he found nearly half a cartload of sticks, iron, and rubbish.

Mr. A. W. Morant remarked that at the beginning of this discussion he specially referred to pipe sewers, for in larger sewers it was of less importance.

Mr. J. Lobley said he had thousands of ventilators, and about a cubic foot of rubbish, stones, chips, &c., was taken out of each pan every three months.

Mr. R. Davies said that in his district the manholes sometimes prove rather dangerous, for in some cases a cart-wheel tilted the cover right off.

Mr. A. W. Morant replied that in Leeds there was no difficulty in regard to the manholes, the covers being all heavy and hinged, and drilled with holes so that they also served as ventilators.

Mr. F. Ashmead remarked that the best way of avoiding expense

was to adopt the Bristol plan, and have no ventilation of the sewers at all, neither by gullies nor manholes.

On the first day of the meeting the Members visited Messrs. Fowler and Sons' Steam Plough and Engine Works. On the second, Messrs. Ingham's Sanitary Tube and Fireclay Works, and the Works of the Farnley Iron Company. On the third day, the Members divided into three parties, one of which visited the Gas Works, another the Sewage Works, Destructors and Carbonizers, and a third party, by the invitation of Mr. Filliter, the engineer to the Leeds Waterworks, visited the Reservoirs in the Washbourne Valley.

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